SITI NUR HAKIMAH BINTI ZAINUDDIN MASTER OF SCIENCE 2025

DIVERSITY AND DISTRIBUTION OF CORAL REEF GASTROPODS IN SELECTED ISLANDS AND MARINE PARK AREAS OF TERENGGANU, MALAYSIA

SITI NUR HAKIMAH BINTI ZAINUDDIN

MASTER OF SCIENCE
UNIVERSITI MALAYSIA TERENGGANU

2025

DIVERSITY AND DISTRIBUTION OF CORAL REEF GASTROPODS IN SELECTED ISLANDS AND MARINE PARK AREAS OF TERENGGANU, MALAYSIA

SITI NUR HAKIMAH BINTI ZAINUDDIN

Thesis Submitted in Fulfilment of the Requirement for the
Master of Science
in the Faculty of Science and Marine Environment
Universiti Malaysia Terengganu

AUGUST 2025

Pusat Pembangunan Pengurusan Akademik (PPPA)
@
Pusat Pengurusan Siswazah (PPS)

Borang Pengesahan Penyerahan Tesis / Disertasi/ Laporan Kertas Projek
Declaration Form for Submission of Theses/ Dissertation / Project Paper

Tajuk / *Title :* DIVERSITY AND DISTRIBUTION OF CORAL REEF GASTROPODS IN SELECTED ISLANDS AND MARINE PARK AREAS OF TERENGGANU, MALAYSIA

Nama Pelajar / *Student's Name* : SITI NUR HAKIMAH BINTI ZAINUDDIN
No. Matrik / *Matric No.*: P4448

Saya dengan ini mengaku membenarkan Tesis/Disertasi/Laporan Kertas Projek ini disimpan di Perpustakaan Sultanah Nur Zahirah, Universiti Malaysia Terengganu ("UMT") dan mengakui bahawa UMT mempunyai hak-hak seperti berikut:
I hereby declare that I have allowed this Theses/Dissertation/Project Paper to be kept by Perpustakaan Sultanah Nur Zahirah, Universiti Malaysia Terengganu ("UMT") and acknowledged that UMT reserves the rights as follows:

1. Hak cipta Tesis/Disertasi/Laporan Kertas Projek ini adalah hak milik UMT.
   The copyright of this Theses/Dissertation/Project Paper belongs to UMT.

2. UMT berhak untuk membuat salinan Tesis/Disertasi/ Laporan Kertas Projek ini untuk tujuan akademik.
   UMT shall has the right to make copies of this Theses/Dissertation/Project Paper for the academic purpose.

3. UMT berhak membuat salinan Tesis/Disertasi/Laporan Kertas Projek ini sebagai bahan pertukaran antara institusi pengajian tinggi.
   UMT shall has the right to make copies for this Theses/Dissertation/Project Paper as an exchange between higher learning institutions.

4. Hak-hak UMT yang dinyatakan dalam perkara 2 dan 3 di atas adalah tertakluk kepada kategori Tesis/Disertasi/Laporan Kertas Projek seperti yang dinyatakan di dalam ini.

The rights of UMT stated in items 2 and 3 above are subject to the category of the Thesis/Dissertation/Project Paper Report as stated herein.

Sila tanda (/) bagi pilihan kategori di bawah:
Please tick (/) from the categories below:

(/)	Tidak Terhad / *Open Access*	Tersedia untuk diakses secara terbuka *Available for open access*
( )	Terhad / *Restricted*	Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan ini dijalankan / *Contains restricted information as specified by the organization/body where research was done.*
( )	Sulit / *Confidential*	Mengandungi maklumat yang dikategorikan di bawah keselamatan atau kepentingan Malaysia seperti yang termaktub dalam Akta Rahsia Rasmi 1972 / *Contains information categorized under the security or interests of Malaysia as stipulated in the Official Secrets Act 1972.*
( )	Embargo / *Embargo*	Tesis ini tertakluk kepada tempoh embargo selama ________ tahun dan tidak boleh diakses oleh umum sehingga tamatnya tempoh tersebut. *This thesis is subject to an embargo of ________ years and shall not be accessible to public until the embargo period ends.*

DR. NURSALWA BAHARUDDIN
Pensyarah Kanan
Fakulti Sains & Sekitaran Marin
Universiti Malaysia Terengganu

Tandatangan Penyelia /
Supervisor's Signature
(Nama dan Cop Rasmi/ *Name & Official Stamp*)

Tarikh/*Date*:7 August 2025

Catatan:

1. Jika Tesis/Disertasi/Laporan Kertas Projek ini SULIT @ TERHAD, sila lampirkan surat dari pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh Tesis/Disertasi/Laporan Kertas Projek ini perlu dikelaskan sebagai SULIT atau TERHAD.
2. Status klasifikasi Tesis/Disertasi/Laporan Kertas Projek hendaklah ditentutkan dan disahkan oleh Penyelia Tesis.
3. Tempoh embargo hendaklah tidak kurang daripada satu (1) tahun dan tidak melebihi lima (5) tahun.

Note:

1. *If this Theses/Dissertation/Project Paper is CONFIDENTIAL @ RESTRICTED, please attach the letter from the relevant authority/organization stating its reason and duration of this Theses/Dissertation/Project Paper should be classified as CONFIDENTIAL or RESTRICTED.*
2. *The classification status of the Thesis/Dissertation/Project Report shall be determined and certified by the Thesis Supervisor.*
3. *The embargo period shall be not less than one (1) year and shall not exceed five (5) years.*

DEDICATION

Dedicated this MSc thesis to:

My supervisors, Dr Nursalwa Baharuddin and Associate Professor Dr. Izwandy Idris,

My beloved parents, SH. Noor Hanisah Syed Hassan and Zainuddin Muda

For all their dedication, sacrifice and endless love

I owe you guys, big time

And to 12-year-old me, who dreamed of becoming a scientist throughout her primary school year even the others doubted the possibility. Thank you for never giving up and trusting in yourself more than anybody else.

You finally did it, Hakimah.

May Allah bless

Abstract of thesis presented to the Senate of Universiti Malaysia Terengganu in fulfilment of the requirements for the degree of Master of Science

DIVERSITY AND DISTRIBUTION OF CORAL REEF GASTROPODS IN SELECTED ISLANDS AND MARINE PARK AREAS OF TERENGGANU, MALAYSIA

SITI NUR HAKIMAH BINTI ZAINUDDIN

AUGUST 2025

Main Supervisor : Nursalwa Baharuddin, Ph.D

Co-Supervisor : Associate Professor Izwandy Idris, Ph.D

Faculty : Faculty of Science and Marine Environment

Coral reefs in Terengganu, Malaysia, provide essential ecosystem services but are increasingly threatened by various disturbances. Gastropods, as key reef bioindicators, highlight the need for conservation within Marine Protected Areas (MPAs). This study was conducted on seven protected islands namely Pulau Bidong, Pulau Kapas, Pulau Perhentian, Pulau Redang, Pulau Tenggol, Pulau Yu Kecil, and Pulau Yu Besar to determine the diversity, distribution and abundance of coral reef gastropods. This study also assessed the age categories and feeding guilds of identified individuals. At each site, a 50 m x 10 m transect line was established within coral areas at depths of 3-12 m, and gastropods were sampled using a 0.0625 m² quadrat with 15 replicates. A total of 704 individuals representing two subclasses, three families and nine species were recorded. Gastropod communities showed low diversity, with Shannon index values ranging from *H'* = 0.506 to 1.154. Species richness ranged from 3 to 5, while equitability scores varied from 0.415 to 0.727. *Drupella rugosa* was the most abundant species, followed by *Arakawania marginalba*. Rarefaction curves at Pulau Bidong, Pulau Kapas and Pulau Perhentian approached asymptotes with three, four and five species were recorded, respectively. In contrast, Pulau Tenggol, Pulau Yu Kecil, and Pulau Yu Besar exhibited gradual increases in species richness, suggesting incomplete sampling. Pulau Redang's curve reached an asymptote rapidly.

Sampling was therefore considered adequate at Pulau Bidong, Pulau Kapas, Pulau Perhentian, and Pulau Redang while species richness at Pulau Tenggol, Pulau Yu Kecil, and Pulau Yu Besar might have been underestimated, implying that further sampling could reveal additional species. Among the recorded species, *Arakawania ceylonica* exhibited the longest shell length at 74.39 mm. Pulau Perhentian emerged as a conservation priority due to the highest percentage of corallivores (28.40%), which may increase coral stress and elevate the risk of population outbreaks. In conclusion, this study provides valuable insights into the diversity and ecological roles of coral reef gastropods in Terengganu, while highlighting their potential threats to coral communities and the need for strengthened conservation strategies within MPAs.

Abstrak tesis yang dikemukakan kepada Senat Universiti Malaysia Terengganu sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

KEPELBAGAIAN DAN TABURAN GASTROPOD TERUMBU KARANG DI PULAU DAN KAWASAN TAMAN LAUT TERPILIH DI TERENGGANU, MALAYSIA

SITI NUR HAKIMAH BINTI ZAINUDDIN

OGOS 2025

Penyelia Utama	:	**Nursalwa Baharuddin, Ph.D**
Penyelia Bersama	:	**Profesor Madya Izwandy Idris, Ph.D**
Fakulti	:	**Fakulti Sains dan Marin Sekitaran**

Terumbu karang di Terengganu, Malaysia menyediakan perkhidmatan ekosistem yang penting tetapi semakin terancam oleh pelbagai gangguan. Gastropod, sebagai bioindikator utama terumbu karang, menekankan keperluan pemuliharaan dalam Kawasan Perlindungan Marin (MPA). Kajian ini telah dijalankan di tujuh pulau perlindungan iaitu Pulau Bidong, Pulau Kapas, Pulau Perhentian, Pulau Redang, Pulau Tenggol, Pulau Yu Kecil dan Pulau Yu Besar untuk menentukan kepelbagaian, taburan dan kelimpahan gastropod terumbu karang. Data juga membolehkan penilaian kategori umur dan kumpulan pemakanan bagi individu yang dikenal pasti. Di setiap lokasi, garis transek 50 m x 10 m diletakkan di kawasan terumbu karang pada kedalaman antara 3-12 m, dan gastropod disampel menggunakan kuadrat 0.0625 m^2 dengan 15 replikasi. Sebanyak 704 individu mewakili dua subkelas, tiga famili dan sembilan spesies telah direkodkan. Komuniti gastropod menunjukkan kepelbagaian yang rendah dengan nilai indeks Shannon dalam julat *H'* = 0.506 hingga 1.154. Kekayaan spesies adalah antara 3 hingga 5, manakala skor keseragaman berbeza antara 0.415 hingga 0.727. *Drupella rugosa* merupakan spesies paling banyak, diikuti oleh *Arakawania marginalba*. Lengkung rarefaksi di Pulau Bidong, Pulau Kapas dan Pulau Perhentian menghampiri asimptot dengan masing-masing tiga, empat dan lima spesies telah direkodkan. Sebaliknya, Pulau Tenggol, Pulau Yu Kecil dan Pulau Yu Besar menunjukkan peningkatan beransur-ansur dalam kekayaan spesies, menandakan persampelan tidak lengkap. Lengkung rarefaksi Pulau Redang pula mencapai asimptot dengan cepat. Oleh itu, persampelan dianggap mencukupi di Pulau Bidong, Pulau Kapas, Pulau Perhentian dan Pulau Redang manakala kekayaan spesies di Pulau Tenggol, Pulau Yu Kecil dan Pulau Yu Besar mungkin telah dianggarkan rendah, menunjukkan bahawa persampelan tambahan boleh mendedahkan lebih banyak spesies. Dalam kalangan spesies yang direkodkan, *Arakawania ceylonica* menunjukkan panjang cangkerang terpanjang iaitu 74.39 mm. Pulau Perhentian dikenal pasti sebagai keutamaan pemuliharaan kerana mencatat peratusan tertinggi koralivor (28.40%), yang berpotensi meningkatkan tekanan terhadap karang serta meningkatkan risiko letusan populasi. Kesimpulannya, kajian ini memberikan maklumat penting tentang kepelbagaian dan peranan ekologi gastropod terumbu karang di Terengganu, serta menekankan ancaman berpotensi terhadap komuniti karang dan keperluan strategi pemuliharaan yang lebih kukuh dalam MPA.

ACKNOWLEDGEMENTS

‘‘In the name of Allah, Most Gracious, Most Merciful.’’

Alhamdulillah, all praise to Allah S.W.T. who put me in the line to finish this thesis. I would like to express my deep sense of appreciation to both my mother, Sharifah Noor Hanisah Syed Hassan and my father, Zainuddin Muda, family members (Muhammad Zulhakim Zainuddin, Siti Nur Hanani Zainuddin, Ahmad Azuan Mohammad, Nurhafizah Othman and Aishah Saleh) for always being there with all the heart-warming advices, continuous prayer and also financial support at the time that I really in the needs of those. Thank you so much for understanding me, always motivating me to finish what I have started and being a major inspirational source whenever I felt down during finishing this research project. Their prayers kept me strong and still holding on until the last moment to complete my Master's degree.

I would like to thank my supervisors, Dr. Nursalwa Baharuddin and Associate Professor Dr. Izwandy Idris, for all the knowledge, advice and opportunities that were given to me while conducting my research throughout the whole period of study. Thank you for always believing in me in whatever I do and giving enough space for me to perform myself. Without them, I do not think I could finish the study and come out with a complete written thesis.

Thanks to all other Universiti Malaysia Terengganu (UMT) colleagues; lab assistants Tuan Haji Razali Bin Haji Salam and En. Syed Ahmad Rizal Tuan Nek for taking pictures of my gastropods. Moreover, thank you so much to my postgraduate friends; Nur Fazne Ibrahim, Nur Hannah Abd Rahim, Fatin Sharmimi Muhammad, Che Engku Siti Mariam Che Engku Abdullah, Nur Amalina Ahmad Rizal, Najihah Abdullah and Aqilah Syahirah Mohd Azhar for lending hands to help me whether it be during the research sampling and also during performing daily routines and discussions with all the lift up conversations that brighten the day. I am thankful to have this excellent team as my co-researchers. Lastly, I thank everyone who helped me directly and indirectly throughout this study.

This research thesis was supported and funded by the Department of Fisheries Malaysia under 'Mini-Expedition on the Marine Life of Terengganu Marine Park: A Post Covid 19 Study' led by Professor Zainuddin Bachok

APPROVALS

I certify that an Examination Committee has met on **5 May 2025** to conduct the final examination of Siti Nur Hakimah binti Zainuddin, on her Master of Science thesis entitled **"Diversity and distribution of coral reef gastropods in selected islands and marine park areas of Terengganu, Malaysia"** in accordance with the regulations approved by the Senate of Universiti Malaysia Terengganu. The Committee recommends that the candidate be awarded the relevant degree. The members of the Examination Committee are as follows:

Fatin Izzati Binti Minhat, Ph.D
Associate Professor,
Faculty of Science and Marine Environment,
Universiti Malaysia Terengganu.
(Chairperson)

Muhammad Hafiz Bin Borkhanuddin, Ph.D
Associate Professor,
Faculty of Science and Marine Environment,
Universiti Malaysia Terengganu.
(Internal Examiner)

Mohd Zacaery Bin Khalik, Ph.D
Senior Lecturer,
Faculty of Resource and Science Technology,
Universiti Malaysia Sarawak.
(External Examiner)

____

WAN MOHD KHAIRUL BIN WAN MOHAMED ZIN
Ph.D
Professor/ Dean
Faculty of Science and Marine Environment
Universiti Malaysia Terengganu

Date:

This thesis has been accepted by the Senate of Universiti Malaysia Terengganu in fulfilment of the requirement for the degree of Master of Science.

WAN MOHD KHAIRUL BIN WAN MOHAMED ZIN
Ph.D
Professor/ Dean
Faculty of Science and Marine Environment
Universiti Malaysia Terengganu

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UMT or other institutions.

____

SITI NUR HAKIMAH ZAINUDDIN

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACY	*Arakawania ceylonica*
AMG	*Arakawania marginalba*
ANOVA	Analysis of Variance
ARD	*Astralium rhodostomum*
ASEAN	Association of Southeast Asian Nation
BBD	Black band disease
BNS	Batu Nisam
BrB	Brown band disease
CA	Carnivorous
CBY	Coral Bay
CCL	*Cerithium columna*
CCR	*Cerithium coralium*
CH	Chagar Hutang
CI	Condition index
cm	Centimetre
cm^2	Centimetre square
CO	Corallivorous
Cont	Continue
CoTS	Crown of thorn starfish
CVL	*Coralliophila violacea*
DCR	*Drupella cornus*
DLG	D' Lagoon
DLT	Dinding Laut
DoFM	Department of Fisheries Malaysia

DRG	*Drupella rugosa*
E	East
e.g.	Exempli gratia
E-value	Evenness value
FoI	*Frequency of Incidence*
g	Gram
HE	Herbivorous
ind/m^2	Individual per metre square
KB	Kerengga Besar
km/h	Kilometre per hour
km	Kilometre
km^2	Kilometre square
KT	Kapas Tengah
log_{10}	Logarithm to the base 10
LW	Lost World
m	Metre
m^2	Metre square
MC	Mak Cantik
MEA	Millennium Ecosystem Assessment
mm	Millimetre
MPA	Marine Protected Areas
mph	Miles per hour
MRS	*Morula spinosa*
MS	Mak Simpan
m/s	Meter per second
N	North
n	Total number of individuals

NIA	Nutrient Indicator Algae
NE	Not Evaluated
PAST	Paleontological Statistical software
PBD	Pulau Bidong
pH	Potential of hydrogen
PKS	Pulau Kapas
PL	Pulau Lima
PPC	Pantai Pasir Cina
PPH	Pulau Perhentian
PPK	Pantai Pasir Pengkalan
PR1	Pulau Rawa South 1
PR2	Pulau Rawa South 2
PRD	Pulau Redang
PRN	Pulau Rawa North
PSB	Pinang Seribu
PTG	Pulau Tenggol
p-value	Probability value
PYB	Pulau Yu Besar
PYK	Pulau Yu Kecil
RAC	Rank Abundance Curve
RJ	Rajawali
S1	Site 1
S2	Site 2
S3	Site 3
SAD	Species Abundance Distribution
SBL	Seabell
SCUBA	Self-Contained Underwater Breathing Apparatus

SEA	Southeast Asia
SHP	Shark Point
SL	Shell length
SN	Sri Nakhota
spp.	species
SR	Silent Reef
ST	Southern Tip
TBS	Tanjung Basi
TGG	Tanjung Genting
TJ	Teluk Jawa
TK	Terumbu Kili
TMP	Terengganu Marine Park
TP	Turtle Point
TPH	Teluk Pauh
TR	Teluk Rajawali
TTG	Terumbu Tiga
UMT MaReST	Universiti Malaysia Terengganu Research Centre
US	United States
3D	Three dimensional
°	Degree
$	Dollar
<	Less than
>	More than
+	Gastropods present
-	None of gastropods present
%	Percentage
±	Plus minus

LIST OF FORMULAS

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Coral reefs, though covering less than one percent of the seafloor are among the most productive and biodiverse ecosystems on Earth (Wagner et al., 2020). Providing essential ecosystem services such as coastal protection, supporting fisheries, and offering opportunities for tourism and recreation, these vibrant underwater communities are vital to both the environment and human societies. Malaysia boasts significant coral reef resources, particularly along its eastern coast including the waters off Terengganu, where 398 coral reef species have been recorded (Lee et al., 2022). These reefs provide a complex habitat structure and a wealth of resources for a multitude of marine organisms, including gastropods. However, these valuable ecosystems are increasingly threatened by a combination of local and global stressors, including pollution, overfishing, and climate change (Tsang, 2017; Rivera et al., 2020; Bai et al., 2024).

Recognising the importance of preserving these invaluable marine resources, Malaysia has established a network of Marine Protected Areas (MPAs), commonly known as marine parks (Tang et al., 2022). These designated areas aim to protect and conserve marine ecosystems by regulating human activities and mitigating harmful impacts. Within the state of Terengganu, four main marine park archipelagos, namely Pulau Redang, Pulau Perhentian, Pulau Kapas, and Pulau Tenggol, provide sanctuary for a rich diversity of marine life, including coral reef gastropods (Safuan et al., 2022). While Pulau Bidong, another significant island in the region, is not formally designated as part of the Terengganu Marine Park, it holds protected status as a Malaysian

National Heritage site, further emphasising the conservation value of these offshore islands.

Gastropods, the largest and most diverse class within the Phylum Mollusca, represent a vital component of marine ecosystems worldwide. Encompassing a vast array of species including limpets, whelks, cowries, abalone, slugs and nudibranchs; these shelled invertebrates also occupy diverse niches and play crucial ecological roles (Dennis et al., 2021). Their presence in various trophic levels, from herbivorous grazing on algae to carnivores preying on other invertebrates, highlights their significance in maintaining the intricate balance of marine food webs (Barrientos-Luján et al., 2021). Furthermore, their sensitivity to environmental changes makes them valuable bioindicators of ecosystem health, reflecting the impacts of both natural and anthropogenic stressors (Samsi et al., 2017). Gastropods can be found in many different kinds of environments, demonstrating their ecological versatility and adaptability.

Several studies have examined coral reef gastropod assemblages in various parts of Southeast Asia, highlighting high species richness and habitat specificity of these molluscs (Mehrotra et al., 2024; Wahyunita & Fahmi, 2024). The findings highlight the ecological importance of gastropods as both functional contributors to coral reefs and sensitive indicators of environmental change. In the Malaysian context, research efforts have begun to document the diversity and ecological roles of coral reef gastropods in Terengganu MPAs. The studies by Baharuddin et al. (2020), Reef Check Malaysia (2020) and Bachok et al. (2021) have documented the diversity of gastropods in selected marine protected areas. However, comprehensive assessments remain limited, particularly across multiple archipelagos in Terengganu. This issue underlines the need for more extensive and comparative research to better understand species distribution and ecological patterns across the region.

This study focuses on coral reef gastropods of the Terengganu marine protected islands in the South China Sea, a region of significant biodiversity and conservation concern. By integrating species-level identification and distributional data across these protected areas, this study highlights the need for more comprehensive, spatially extensive and ecologically informed studies that not only document species presence but also examine distribution patterns, habitat associations and inter-island variations. Addressing these research gaps is essential for informing a more comprehensive understanding of gastropod biodiversity and supporting evidence-based management of Malaysia’s coral reef ecosystems.

1.2 Problem statement and significance

Despite the recognised importance of gastropods in marine ecosystems and the establishment of Marine Protected Areas (MPAs), a significant knowledge gap exists regarding the diversity, distribution and ecological roles of coral reef gastropods within Terengganu islands (Baharuddin et al., 2020). This gap stems primarily from the absence of comprehensive baseline data and incomplete species checklists, which are critical for assessing biodiversity trends and detecting potential decline (Lopes-Lima et al., 2021). Without such foundational information, it is difficult to determine whether gastropod diversity is increasing or declining, thereby limiting the ability of conservation managers to evaluate the effectiveness of MPAs (Shaver et al., 2020). This issue also highlights a broader challenge across Malaysian MPAs where baseline biodiversity data especially for invertebrate taxa including gastropods remain sparse and outdated, impeding long-term monitoring and conservation planning (Masud, 2019; Chen, 2021). To bridge this gap, it is essential to review and integrate findings from previous research conducted within Malaysian Marine Parks or equivalent MPAs globally. Studies from MPAs in the Indo-West Pacific region, Caribbean, Mediterranean and Southeast Asia countries including Thailand have highlighted several challenges in assessing gastropod biodiversity. These include limited taxonomic expertise, under-sampling of microhabitats, seasonal variation in species presence and inconsistent survey methodologies across sites (Bouchet et al., 2002; Albano et al., 2021; Canteri, 2024).

Meanwhile, studies conducted within Malaysian Marine Parks have identified several constraints in gastropod assessments. These include the difficulty of locating species due to habitat complexity, the frequent oversight of ecologically important species and short-term surveys that may not capture seasonal or temporal variability (Baharuddin et al., 2020; Bachok et al., 2021). As a result, existing checklists remain incomplete, hindering comprehensive conservation efforts. This incompleteness limits the utility of these checklists for long-term biodiversity monitoring as it becomes difficult to detect trends, identify areas of high conservation priority and evaluate the effectiveness of MPAs (Sullivan-Stack et al., 2024).

Gastropods play a vital role in coral ecosystems, functioning both as ecological indicators and key contributors. Representing one of the most species-rich invertebrate groups in marine environments, the gastropods are widely distributed across reef zones and occupy a variety of microhabitats such as coral rubble (Saponari et al., 2021), sandy substrates (Rizki, 2019), seagrass beds (Vian et al., 2022) and coral crevices (Kamerman, 2023). Their diverse morphologies, feeding behaviours and life history traits allow them to fulfil their ecological functions that are essential for coral reef health (Delgado & Sharp, 2020; Barrientos-Luján et al., 2021; Herbert et al., 2023). Furthermore, gastropod diversity and distribution reflect the stability of marine habitats particularly coral reefs, making them effective bioindicators for monitoring environmental changes and anthropogenic impacts (Floyd et al., 2020). This is because the gastropods can occupy various ecological niches, ranging from herbivores that prevent algae overgrowth and enhance coral reproduction (Lippens, 2025) to carnivores that regulate prey populations, maintain trophic balance and promote biodiversity within coral ecosystems (Motti et al., 2022). Consequently, changes in gastropod diversity often signal shifts in environmental conditions, offering early warnings of ecosystem degradation. Assessing the age structure of gastropod populations is also essential as it provides valuable insights into the growth rates, population recruitment and reproductive output (Maxwell, 2021; Herbert et al., 2022). Understanding the different age classes within gastropod communities helps identify ecological stressors and guide conservation strategies to conserve gastropod populations.

This study aligns with the National Policy on Biological Diversity 2016-2025, specifically Goal 1, which promotes sustainable use of biodiversity among stakeholders and Target 1, which increases awareness of biodiversity values among

Malaysians (Ministry of Natural Resources and Environment, 2016). By providing baseline data on gastropod diversity in coral reef ecosystems, this study can inform stakeholders about management strategies, support the development of targeted conservation measures and enhance public awareness of coral ecosystems. The study addresses the current knowledge gap by investigating species diversity, distribution patterns, age structure (using shell length as a proxy) and feeding guilds of coral reef gastropods within marine protected areas. This information provides crucial baseline data for understanding the ecological dynamics of gastropod communities and developing effective management strategies for long-term conservation of vital marine habitats.

1.3 Research questions

1. What is the diversity, distribution and abundance of coral reef gastropods among and within islands?
2. How do shell metric and biomass of coral reef gastropods vary among and within islands?
3. What are the feeding guilds of coral reef gastropods among and within islands?

1.4 Hypothesis

1. The diversity of coral reef gastropods in Terengganu marine protected islands is low.

2. The value of shell metric and biomass varied between the islands.

3. The highest percentage of feeding guild for coral reef gastropods is the corallivore group.

1.5 Objectives of study

The objectives of this study are:

1. To determine diversity, distribution and abundance of coral reef gastropods among and within islands.
2. To assess shell metric and biomass of identified coral reef gastropods among and within islands.
3. To characterize feeding guilds of coral reef gastropods among and within islands.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of coral reefs

2.1.1 Overview of coral reef ecosystems

A single coral is composed of many tiny invertebrates known as polyps (Donovan et al., 2023). They are generally attached to substrates such as rocks or the ocean floor to form reef carbonate skeletons. The polyps in a colony are linked by living tissue and can share food among neighbouring individuals. Each coral polyp contains zooxanthellae algae, which have a symbiotic relationship with corals (Titlyanov & Titlyanova, 2020). While the zooxanthellae algae transported photosynthetic products such as organic carbon, the coral protects microalgae within the polyp tissue (Bara'langi et al., 2021). The organic carbon is primarily in the form of glycerol, which is used by corals for metabolic functions such as protein synthesis and biomass buildup (Linsmayer et al., 2020). To form a reef skeleton, coral polyps extract calcium and carbonate ions from the surrounding seawater (Khalifa et al., 2021).

Coral reef growth and health are influenced by environmental conditions such as light, water movement and invertebrate marine species, which can impact corals in both beneficial and harmful ways (Barton et al., 2020; Hossain & Staples, 2020; Kuanui et al., 2020). Light enhances the photosynthetic activity of zooxanthellae algae, thereby boosting coral metabolism and calcification (Briggs & Carpenter, 2019). However, some studies have shown that low light levels can reduce photosynthate production and weaken skeletal formation (Kahng et al., 2019; Kramer et al., 2023). Water movement facilitates nutrient delivery and prevents fouling organisms from settling on the coral surface, though excessive flow may deform polyps and impair nutrient uptake (Jones et al., 2019; Samson et al., 2019).

Some invertebrates can alter coral skeleton in ways that affect nutrient dynamics and reef structures (Barton et al., 2020). For example, sponges attach to coral skeletons and release nutrient-rich effluent water that benefits the coral hosts (Pawlik & McMurray, 2020). Crabs from Cryptochiridae create small holes on coral skeletons to facilitate filter feeding (Chan et al., 2020). While these interactions can enhance nutrient availability for coral hosts, they may also have negative impacts by reducing growth or consuming coral tissue (Brandt et al., 2019; Bravo et al., 2024). These examples illustrate both the positive and negative effects of coral-associated invertebrates, which may also apply to molluscs particularly corallivorous gastropods that physically and biologically alter reef environments (Ruan, 2021; Zhang et al., 2024; Rani & Roy, 2025)

2.1.2 Coral reefs ecosystem services

Ecosystem services refer to a broad range of benefits provided by natural resources and ecological processes. Coral reefs can offer various services to the environment and human societies (Hoegh-Guldberg et al., 2019). According to Millennium Ecosystem Assessment (MEA) categories, coral reef ecosystem services can be classified into provisioning services (Alemu et al., 2021), cultural services (Niz et al., 2023), supporting services and regulating services (Brathwaite et al.,2022).

Provisioning services are benefits produced by the coral reef ecosystem, mainly divided into two main groups; fishery and materials (Woodhead et al., 2019). Coral fisheries provide essential sources of protein and income, particularly in rural areas where dependence on marine resources is high (Chaijaroen, 2022). Additionally, coral materials are harvested in some regions for land reclamation and some coral species are collected globally for curio trades (Sosnowski et al., 2020).

Cultural services are non-material benefits such as tourism and spiritual values that enhance human experiences and livelihoods. Coral reef tourism generates an estimated US$375 billion annually and sustains livelihoods across more than 100 jurisdictions (Kamaludin et al., 2021). The aesthetic appeal of many different forms of reef organisms including gastropods adds to both cultural and economic value of coral reefs (Moretzsohn, 2023).

Regulating services are the benefits obtained from ecological regulations process such as coastal protection and water quality cycling (Grizzetti et al., 2019; Woodhead et al., 2019). Coral reef structures can dissipate wave energy and reduce coastal erosion during extreme weather events (Joy et al., 2021; Viehman et al., 2023). Additionally, they also support water filtration through filter-feeding organisms including molluscs and other invertebrates to improve water quality (Richard et al., 2024).

Supporting services refer to the ecological functions of coral reefs that provide key habitat to many marine organisms. Their complex three-dimensional (3D) structures serve as species refugia and ecosystem engineers (Rinkevich, 2021). The 3D structure of coral reefs is strongly associated with the diversity, abundance and biomass of gastropods because most benthic organisms rely on this ecosystem for shelter and food (Burns et al., 2019).

2.1.3 Regional coral reefs diversity and distribution

The Indo-West Pacific, particularly the Coral Triangle, is the global centre of marine biodiversity by hosting over 600 scleractinian corals and represents nearly 75% of the world's reef species (Yusuf et al., 2019; Sobha et al., 2023). Within the Coral Triangle, Malaysia is recognised for its high coral diversity especially along the east coast of Peninsular Malaysia and in Sabah (Safuan et al., 2020). Terengganu, a state on the eastern coast of Peninsular Malaysia is renowned for its vibrant coral reefs, with branching and massive corals being the most dominant species (Akmal et al., 2019; Safuan et al., 2021). Branching corals such as *Acropora* spp. are fast-growing and form complex, tree-like structures that enhance habitat complexity and support high biodiversity (Speare et al., 2023). In contrast, massive corals like *Porites* spp. grow slowly into dome-shaped structures that are more tolerant of wave action and thermal stress (Akmal et al., 2019; Isdianto et al., 2024).

Despite their ecological importance, the coral reefs in Terengganu have experienced various disturbances from both natural and anthropogenic factors (Safuan et al., 2022). Among natural stressors, the outbreak of corallivores including gastropods plays a significant role in reef degradation (Baharuddin et al., 2017; Tsang et al., 2017). In addition to natural disturbances, human-induced pressures such as overfishing and pollution have become major drivers of coral reef decline in the region (Marzo et al., 2023).

2.2 Marine Protected Areas (MPAs)

The government of Malaysia has established marine parks, which are also recognised as Marine Protected Areas (MPAs). MPAs are specific management tools used to zone marine ecosystems in order to minimise the impact of anthropogenic activities, promote the recovery of ocean ecosystem and enhance their services to nature and human well-being (Safuan et al., 2022). A primary objective of MPA is to protect and reduce the decline of marine ecosystems and biodiversity, particularly coral reefs (Rahman et al., 2019). According to Safuan et al. (2022), Malaysia signed and ratified the Convention on Biological Diversity (CBD) in 1992 and 1994, demonstrating the country's commitment to the broader biodiversity conservation in the region. The CBD has served as a catalyst to the increment of marine parks in Malaysia. Initially, the Department of Fisheries Malaysia was responsible for managing marine parks in Peninsular Malaysia. However in 2007, marine parks were administered under the Ministry of Natural Resources and Environment (Mokhtar et al., 2020). To date, 42 marine parks have been designated across Peninsular Malaysia including in Johor, Kedah, Pahang, Melaka and Terengganu with 13 parks located specifically in Terengganu.

Terengganu Marine Parks cover a total area of 591.37 km^2 and serve as popular tourist destinations that contribute significantly to government revenue and support local businesses through the tourism industry (Safuan et al., 2022). The main marine park archipelagos in Terengganu were Pulau Perhentian, Pulau Redang, Pulau Kapas and Pulau Tenggol, located in the South China Sea off the east coast of Peninsular Malaysia (Table 2.1). In addition, Terengganu also has a historically significant island, Pulau Bidong, which is known as 'Little Saigon' by the local people (Daud et al., 2022). Although Pulau Bidong is not officially designated as a marine park, the Terengganu government has gazetted it as a significant asset in recognition due to its cultural, historical and ecological values (Ridzuan et al., 2022). Pulau Bidong is known for its historical symbol of ASEAN solidarity that accommodated refugees fleeing Vietnam after the war. Since 2010, the island has become the site of Universiti Malaysia Terengganu Research Centre (UMT MaReST). Terengganu islands harbour diverse and rich reef ecosystems that have attracted many visitors, leading to the development of various infrastructures in the islands (Safuan et al., 2022).

The establishment of MPAs is crucial not only for preserving but also for protecting important associated marine biodiversity including invertebrate communities such as gastropods (Saleh et al., 2020). MPAs have significantly contributed to biodiversity conservation by providing refugia for marine species, supporting population recovery and maintaining ecological interactions (Grorud-Colvert et al., 2021; Gilmour et al., 2022; Hadiyanto et al., 2022). From the perspective of ecosystem resilience, marine protected areas help to buffer coral reefs against anthropogenic stressors such as overfishing, pollution and coastal development, allowing ecosystems to better recover from disturbances (Good et al., 2021; Ceccarelli et al., 2022). By preserving coral reef habitats, MPAs help maintain the environmental complexity and microhabitats that are vital for the survival and reproduction of marine organisms, especially gastropods (Chen, 2021; Riera et al., 2024). In conclusion, Terengganu's MPAs not only serve socio-economic purposes but also act as important conservation tools that support the long-term sustainability of marine biodiversity, particularly coral reef ecosystems (Masud et al., 2022; Safuan et al., 2022).

Table 2.1 List of marine parks in Terengganu (Safuan et al., 2022).

Marine Park	Gazetted (Year)	Location	Distance from mainland (km)	Islands
Perhentian	1994	Besut District 5°54’35.09”N 102°44’16.77”E	16.0	Perhentian Besar, Perhentian Kecil, Susu Dara
Redang	1994	Kuala Nerus District 5°47’2.68”N 103° 0’25.75”E	23.0	Redang, Pinang, Lima, Ekor Tebu, Yu Besar, Yu Kecil, Lang Tengah
Kapas	1994	Marang District 5°13’8.35”N 103°15’53.82”E	5.0	Kapas
Tenggol	1994	Dungun District 4°48’27.23”N 103°40’45.19	28.0	Tenggol, Nyireh

2.3 Diversity and distribution of gastropods

Phylum Mollusca is one of the most diverse and notable groups in the animal kingdom, inhabiting all environments ranging from deep sea to terrestrial domains. Molluscs are soft-bodied invertebrates with complex structures that protect their soft tissues from predation and prevent desiccation. Gastropoda is one of the classes within Phylum Mollusca, comprising more than 10,000 species. Most gastropods possess coiled shells and an operculum, which help close the shell and protect the animal (Dennis et al., 2021). The main body parts are the head, foot and visceral mass (Sonak, 2017). The head bears sensory organs such as tentacles, eyes and mouths. It typically protrudes anteriorly from the shell, while the foot is a muscular ventral organ with a flattened base used for locomotion. The visceral mass fills the spire of shell. The characteristics of gastropods are illustrated in Figure 2.1.

Gastropods are incredibly versatile and have adapted to various habitats, making them one of the most diverse invertebrate groups worldwide. They inhabit freshwater, terrestrial and marine and within these, they can occupy a range of microhabitats including coral reefs (Zainuddin et al., 2024). Environmental conditions, ecological interactions and anthropogenic factors can all influence the diversity and distribution of gastropods. Stella et al. (2022) found that coral reef structures play crucial roles in shaping gastropod communities. For example, branching corals support more species than massive or foliose corals. This is because the volume of coral heads and spaces between the coral branches serve as shelters, protecting gastropods from wave action and predators (Sheppard, 2021). Additionally, gastropod distribution may also be influenced by ecological interactions such as competition, predation and nutrient availability, which support both diversity and abundance (Laheng et al., 2023). However, human impacts include fisheries and over-tourism can lead to habitat degradation and physical disturbance to coral communities, ultimately altering gastropod diversity and affecting other coral-associated marine organisms on a global scale (Mohanraj et al., 2015).

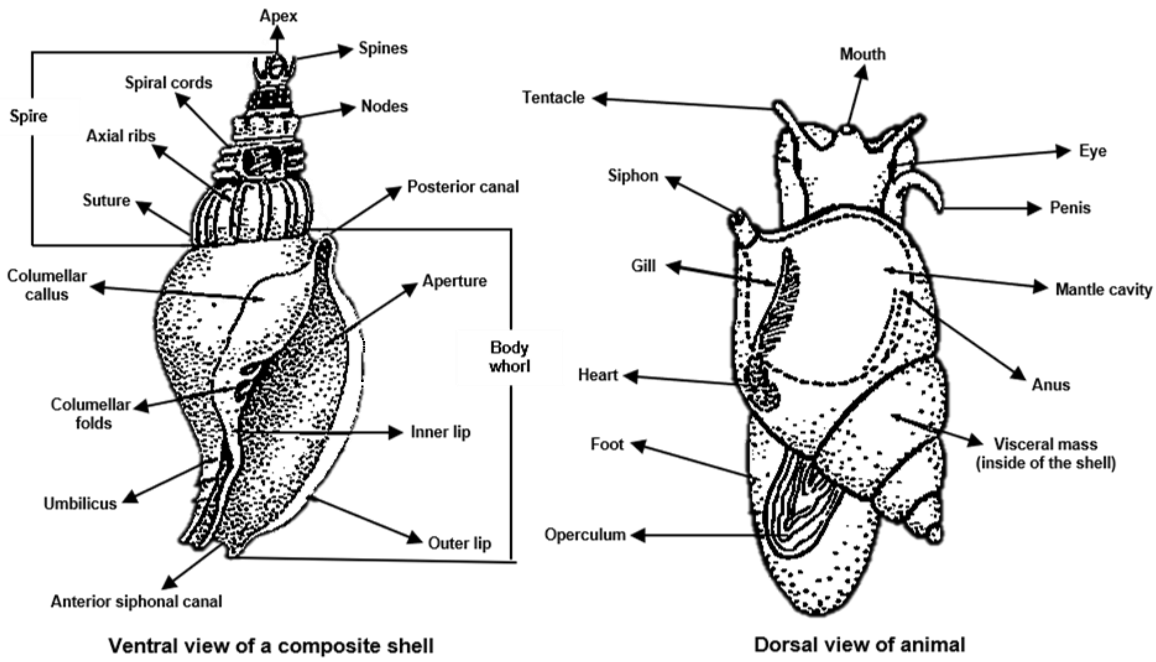

Figure 2.1 General characteristics of gastropod (Source: Zakaria, 2013).

2.4 Coral reef gastropods in Southeast Asia

2.4.1 Patterns of species diversity and distribution in tropical regions

Coral reef molluscs are diverse invertebrates inhabiting marine environments, and several MPAs in Southeast Asia have conducted studies on gastropods. Gittenberger et al. (2015) investigated marine gastropod species on mushroom coral reefs as biological bioindicators in Halmahera Mollucas, Indonesia. The researchers identified 27 species of coral-associated gastropods from two families; Epitoniidae and Coralliophilidae (Table 2.2). Similarly, Rahmayanti et al. (2018) recorded 13 genera of marine gastropods on Wangi Island, Indonesia. *Mitra* gastropods from the Mitridae family had the highest number with 86 individuals, followed by *Collumbella* (40) and *Conus* gastropods (35), respectively.

Another study on coral mollusc species was conducted in the Sattahip district of Thailand by Sanpanich and Duangdee (2015). The research focused on the classes Bivalvia and Gastropoda. Most species were found at Nang-Rong Beach, likely due to the wider and longer coral reefs in that area. The assessment identified 17 gastropod families in the coral reef area (Table 2.2). Herbivorous gastropod families such as Columbellidae, Trochidae and Turbinidae were abundantly recorded due to the high percentage of marine algae in the Nang-Rong Beach area.

On the other hand, Sanpanich and Duangdee (2018) reported 181 gastropod species from 53 families and 97 bivalve species from 26 families in the Southern Mergui Archipelago, Myanmar (Table 2.2). The most common gastropods were *Chicoreus ramosus* (Muricidae) and *Astralium rhodostomum* (Turbinidae). The Muricidae family inhabits a wide range of coastal and marine habitats, including coral reefs. *Astralium rhodostomum* was the second most abundant species due to the high algae coverage on coral reefs.

Lastly, an assessment of coral reef gastropods in Southeast Asia's MPAs also was conducted by Prieto-Amador and Palomar-Abesamis (2024) in the Philippines. They identified seven species of gastropods, namely *Cerithium* sp., *Conus* sp., *Cyprae tigris*, *Ovula ovum*, *Lambis* sp., *Tonna* sp. and *Rochia nilotica*. The presence of certain gastropods such as *Conus* sp. and *Lambis* sp. in both coral reefs and seagrass substrates suggests their adaptability to multiple habitats (Prieto-Amador & Palomar-Abesamis, 2024).

These studies highlight the ecological importance of gastropods within coral ecosystems. Gastropods fulfil a variety of functional roles, including herbivory, carnivory and corallivory (Motti et al., 2022; Zhang et al., 2024; Lippens, 2025). For instance, the dominance of herbivorous families such as Ceriithidae, Columbellidae, Trochidae and Turbinidae in algae-rich environments underscore their roles in controlling algae growth and maintaining coral health (Barbosa et al., 2019; Benítez et al., 2022; McMullin et al., 2024). In addition, predatory species such as *Conus* sp. and *Chicoreus ramosus* (Muricidae) function as trophic regulators, influencing the population dynamics of their prey within coral communities (Sakilan, 2021; Ratibou et al., 2024). The Muricidae family occupies a broad range of marine habitats and is recognised for its diverse ecological roles, ranging from predation to structuring coral communities (Baharuddin et al., 2019; Tan et al., 2024).

Moreover, the presence of gastropods in Halmahera Moluccas, Indonesia such as Coralliophilidae (corallivores) and Epitoniidae (carnivores) can reflect the health, structure and functionality of coral reef ecosystems (Rice et al., 2019; Nützel, 2021). These coral-associated gastropods play important roles with epitoniids functioning mainly as parasites of cnidarians, while coralliophilids act as corallivores by feeding on live coral tissue (Gautrand et al., 2023; Mehrotra et al., 2024). Additionally, a variety of carnivorous, herbivorous and omnivorous gastropods have been recorded on Danjungan Island, Philippines (Prieto-Amador & Palomar-Abesamis, 2024). Each feeding guild of gastropods demonstrates their ecological versatility and roles in trophic regulation, benthic community structure and nutrient cycling across various habitats (Morillo-Velarde et al., 2018; Mies et al., 2024). Their presence contributes to reef trophic dynamics and makes them sensitive bioindicators of coral health.

Despite their crucial ecological roles, gastropods and particularly their coral habitats are increasingly threatened by numerous conservation challenges (Bravo et al., 2021; Chen, 2021). Coral-associated gastropods especially corallivores, herbivores and carnivores are ecologically significant due to their close dependence on live coral hosts. The continued degradation of coral reefs from ocean acidification and pollution directly affects habitat availability for these specialised taxa (Young & Gobler, 2020; Zhang et al., 2024). Ocean acidification reduces the availability of aragonite and calcite, which are vital for coral skeleton formation, thereby weakening coral structures that provide essential microhabitats for gastropods (Masanja et al., 2024). Furthermore, pollution from agriculture and coastal development reduces water quality, promotes algae growth and hinders coral larvae settlement, leading to a shift from coral-dominated to algae-dominated reef ecosystems (Wang et al., 2020; Fairoz, 2022; Zahoor & Mushtaq, 2023). While this transition may temporarily benefit herbivorous gastropods, they ultimately indicate ecosystem decline and reduced biodiversity (Delgado & Sharp, 2020; Bieg et al., 2024). The long-term survival of gastropods fundamentally depends on coral reef health and resilience. Therefore, the protection and preservation of coral ecosystems are essential not only for sustaining gastropod diversity but also for maintaining the overall health of marine ecosystems (Barrientos-Luján et al., 2017; Voolstra et al., 2023).

Table 2.2 Coral reef gastropod studies in Southeast Asia MPAs.

Methodology	Study	Location (MPAs)	Substrate	Family	Genus
Transect line and quadrat	Gittenberger et al. 2015	Indonesia (Halmahera Moluccas)	Mushroom coral reefs	2	2
	Rahmayanti et al. 2018	Indonesia Wangi-wangi Island	Fringing coral reefs and fine sand	12	13
	Sanpanich & Duangdee, 2015	Thailand (Sattahip District)	Coral reefs	17	28
	Sanpanich & Duangdee, 2018	Myanmmar (Mergui Archipelago)	Coral reefs and sandy beaches	53	114
	Prieto-Amador & Palomar-Abesamis, 2024	Philippines (Danjungan Island)	Coral reefs and seagrass beds	7	7

2.5 Coral reef gastropods in Malaysian MPAs

To date, various attempts have been made to determine the diversity of coral reef gastropods in Malaysian MPAs. However, most gastropods inhabiting coral reefs have only been documented in conference papers and technical reports. Previous research has focused mainly on conservation sites, which are particularly relevant studies due to the sustainable management efforts begun.

In Terengganu, Baharuddin et al. (2017) studied the population dynamic of corallivorous gastropod *Drupella rugosa*, recording 401 individuals in Pulau Redang. The researchers reported a significant difference in shell length among *Drupella rugosa* due to the different cohort species. Further research on gastropods at coral reefs was conducted by Baharuddin et al. (2020) at Pulau Redang, Pulau Perhentian, Pulau Kapas and Pulau Tenggol. *Drupella rugosa* was the most frequently encountered corallivorous species across all islands. *Tenguella marginalba* and *Morula spinosa* were the second most abundant, and while *Cerithium columna*, *Cerithium coralium* and *Drupa ricinus* were among the least recorded.

In addition, Reef Check Malaysia (2020) reported the presence of corallivorous gastropod, *Drupella* spp. (Muricidae) in the states of Johor and Melaka. Bachok et al. (2021) also recorded 97 gastropods from Muricidae family in Pulau Yu Besar and Pulau Yu Kecil. *Drupella rugosa* was the most abundant species across all surveyed sites. However, many gastropods were likely missed due to their cryptic locations and patchy distribution. The researchers suggested that the actual abundance may be higher than recorded.

Zainuddin et al. (2024) documented 112 individuals belonging to two subclasses (Caenogastropoda and Vetigastropoda) and two families (Muricidae and Turbinidae) in Pulau Redang. The identified species included *Astralium rhodostomum, Drupella rugosa, Morula spinosa* and *Tenguella marginalba*.

While these studies provide valuable insights into species diversity and distribution in Malaysian MPAs, significant knowledge gaps remain regarding the ecological roles of gastropods in coral ecosystems. Assessing their functional contributions such as coral predation, algae grazing and prey regulations are essential for coral community structure (Ruan, 2021; Motti et al., 2022; Fasila & Vinod, 2024). However, limited information on these roles in Malaysia hampers our understanding of their functional significance. Moreover, the diversity, distribution and ecological functions of gastropods are increasingly threatened by habitat degradation, climate change, ocean acidification and anthropogenic disturbances such as overfishing and pollution (Marshall & McQuaid, 2020; Stella et al., 2022; Marzo et al., 2023; Li et al., 2025). Without a better understanding of gastropod roles and the pressures they face, conservation strategies may overlook key components essential for maintaining the resilience and ecological balance of coral reef ecosystems (Chen, 2021).

Table 2.3 Previous coral reef gastropod studies in Malaysian MPAs.

Methodology	Study	State	Location	Family	Genus
Transect line and quadrat	Reef Check Malaysia 2020 (Technical report)	Johor	Pulau Aur, Pulau Dayang	1	1
	Reef Check Malaysia 2020 (Technical report)	Melaka	Pulau Sembilan	1	1
	Baharuddin et al. 2017 (Technical report)	Terengganu	Pulau Redang	1	1
	Baharuddin et al. 2020 (Technical report)		Pulau Redang, Pulau Perhentian, Pulau Kapas, Pulau Tenggol	3	7
	Bachok et al. 2021 (Technical report)		Pulau Yu Besar, Pulau Yu Kecil	1	3
	Zainuddin et al. 2024 (Article)		Pulau Redang	2	4

2.6 Shell metric and biomass of gastropods

Shell metrics refer to quantitative measurements of gastropod, including both external (shell length, shell width) and internal (aperture length, aperture width) dimensions. These measurements offer valuable ecological insights into coral reef gastropod communities (Obaza & Ruehl, 2013). External measurements reflect the growth of gastropods, while the aperture plays a crucial role in allowing their emergence and withdrawal (Allsay & Dwi, 2023). In measuring shell metrics, shell length is taken from the apex of the shell to the base of aperture, while shell width is measured at the widest part of the body whorl (IDTools, 2022). Aperture measurements include aperture length, which is the longest distance across the aperture and aperture width is the widest distance across the aperture. Biomass is the total weight of all organisms in a specific area, and gastropod's biomass is typically measured as dry weight or ash-free dry weight (Eklöf et al., 2023). Eklöf et al. (2023) also reported that biomass is one of the fundamental variables in ecology, playing a crucial role in studies ranging from ecophysiology and food web interactions to whole-ecosystem metabolism.

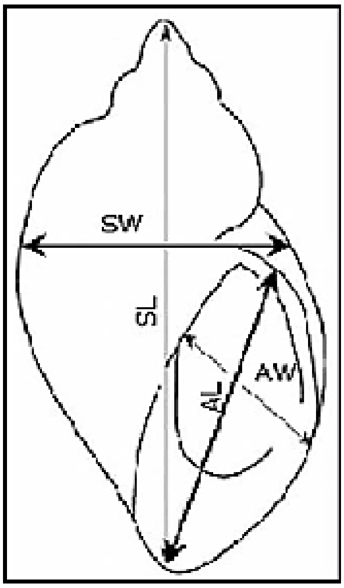

Figure 2.2 The shell metrics of the gastropod: shell length (SL), shell width (SW), aperture length (AL) and aperture width (AW) (Source: Baharuddin et al., 2019).

2.7 Ecological roles and feeding guilds of gastropods

Gastropods play several crucial roles in the marine ecosystem surrounding the offshore islands of Terengganu in the South China Sea. They contribute to ecosystem health and stability by serving as bioindicators to assess the ecological condition of coral communities. Feeding guilds classify groups of species that share similar food resources, based on the idea that closely related species often exhibit similar feeding behaviours (Sánchez-Hernández, 2020). Coral reef gastropods consist of several functional groups such as corallivores, carnivores, herbivores and bioeroders, each contributing uniquely to maintaining coral reef health (Kamerman, 2023; Mies et al., 2024). Maintaining optimum proportions of these feeding guilds of gastropods are essential for the stability of coral ecosystems. For example, corallivorous gastropods influence coral population dynamics (Ruan, 2021), herbivores help control algae overgrowth (Lippens, 2025), carnivores regulate coral predator population (Motti et al., 2022) and bioeroders contribute to substrate turnover and availability (Luthfi & Priyambodo, 2020). Therefore, any imbalance among these functional groups may indicate ecological stress, potentially leading to reduced coral resilience and biodiversity (Knoester, 2023).

2.7.1 Corallivores

Corallivory is the predation of coral tissues and corallivores are organisms that rely on coral reefs as their primary food resources (Tsang, 2017). In 1842, Charles Darwin reported the first occurrence of corallivory after discovering fragments of coral reefs in the intestines of *Scarus* fishes during his research trip to Cocos-Keeling Atoll. Corallivorous gastropods belonging to the genera of *Drupella* and *Coralliophila* can impact coral ecosystems at multiple levels, from the individual to entire coral communities (Lei et al., 2022). *Drupella* species use a specialised feeding organ called the radula to scrape coral tissue from the carbonate skeleton, leaving feeding scars marked by white spots. While *Drupella* naturally occurs in coral reef ecosystems, their uncontrolled aggregations can lead to population outbreaks (Canteri, 2024). An outbreak is defined as a sudden and rapid increase of coral predators above the density of coral communities can sustain. The first population outbreak of *Drupella* occured in Japan (Bessey et al., 2018). These outbreaks have caused substantial damage and negative impact on coral reef populations as demonstrated by researchers in Hong Kong, Kenya, Red Sea, Western Australia (Canteri, 2024). The aggregation of *Drupella* poses a serious threat as their aggressive behaviour leads to extensive tissue loss, transmits diseases and reduces live coral cover (Barton et al., 2020; Renzi et al., 2022; Tan et al., 2024). Therefore, these detrimental impacts highlight the paramount importance of protecting coral reefs and mitigating the consequences of corallivore outbreaks, which can threaten the health of entire coral ecosystems (Rice et al., 2019).

Marine gastropods from *Corallipophila* genus are corallivores, although these snails lack typical feeding structures such as radula and jaws to feed coral tissues. *Coralliophila* genus is sedentary animals by attaching themselves to coral colonies and obtaining their food by sucking up photosynthate that corals transport to their injured tissue (Simmonds et al., 2018). When *Coralliophila* snails interact with *Acropora* corals, they cause more visible damage than other coral genera, and this gastropod is mostly clustered together due to chemical substances in mucus released by stressed corals (Hamman, 2018). Several predators such as the spiny lobster *Panulirus argus,* snapping shrimp *Synalpheus fritzmuelleri* and the muricid rock snail *Thais deltoidea* are capable of controlling the aggregation of corallivorous snails at coral reefs (Shaver et al., 2020).

Moderate corallivory can still induce changes and serve as a form of biological control within coral communities (Rice et al., 2019). The corallivorous gastropods can influence coral reef composition by preying on fast-growing corals such as *Acropora, Montipora* and *Pocillopora*, thereby allowing the coexistence of other coral genera within the same marine environments (Ruan, 2021). However, when predation becomes intense, these gastropods can affect the overall health of coral communities by facilitating the transmission of various diseases. According to Munk (2024), injured corals tend to exhibit slower growth rates because a proportion of their energy is redirected to wound recovery sites, leaving limited energy for overall growth. The corallivorous snails are known as disease vectors by introducing pathogen agents such as *Serratia marcescens* to initiate coral diseases such as white spots, yellow band, black band disease (BBD) and brown band disease (BrB) (Subhan et al., 2020; Renzi et al., 2022).

2.7.2 Carnivores

Carnivorous gastropods feed on organisms such as sponges, barnacles, tunicates, echinoderms and molluscs, and they often co-exist within the same coral reef habitat as coralivorous gastropods (Averbuj et al., 2021). According to Delgado and Sharp (2020), some carnivorous gastropods such as *Thais deltoidea* can predate and control corallivorous snails from the *Coralliophila* genus. In addition, triton giant snails have also been proposed to prevent other forms of corallivores such as crown-of-thorns starfish (Motti et al., 2022). They concluded that the presence of carnivorous gastropods could benefit coral reef conservation efforts by reducing corallivores that feed on living coral tissue, as corallivores can hinder coral growth and develop other coral stressors such as diseases (Delgado & Sharp, 2020).

2.7.3 Herbivores

Coral reefs face threats globally and undergo phase shifts from coral to algae-dominated communities. A phase shift occurs when the balance between algae-coral is disturbed, leading to replacement of live coral cover with dense algae (González et al., 2017). Algae typically exist in low density but when coral colonies are disturbed, the opportunistic or fast-growing algae rapidly colonise the exposed coral skeletons (McManus & Polsenberg, 2004). The interspecific competition between corals and algae is often driven by limited space and resources such as sunlight. In this context, the presence of herbivorous gastropods is essential to improve coral survival by grazing on overgrowing algae (Feitosa, 2024; Neil et al., 2024). Herbivorous gastropods are organisms that consume algae such as turf algae (Figueiredo et al., 2020), microalgae (Fasila & Vinod, 2024) and crustose coralline algae (Castejón et al., 2023). Henry et al. (2019) stated that herbivorous species such as *Lithopoma americanum* (Turbinidae*), Batillaria minima* (Batillariidae) and *Trochus niloticus*

(Trochidae) can enhance coral survival by uncovering underlying substrates, including dead coral skeletons for larvae recruitment. Furthermore, the ability of herbivorous gastropods to reduce algae biomass also decreases algae overgrowth on juvenile corals, thereby facilitating their growth (Lippens, 2025).

2.7.4 Bioeroders

Bioeroders are organisms that can break down carbonate substrates and modify reef structures (Fordyce et al., 2020). Gastropods exhibit bioeroder mechanisms capable of eroding and weakening the coral skeleton through their activities, potentially contributing to coral structural degradation. However, bioerosion also plays an important ecological role in regulating coral dynamics by breaking down dead coral and creating new substrate for settlement of sedentary larvae species (Luthfi & Priyambodo, 2020).

Regardless of their importance and roles in coral reef ecosystems, some molluscan fauna such as vermitid gastropods have notable effects by deforming coral reef structures (Adhavan et al., 2021). The coral reefs often provide a habitat for slow-moving organisms but high density of vermitid gastropods can potentially deform coral morphology (Hoeksema et al., 2022). The sessile gastropods are abundant and typically embed themselves on coral reef skeletons. The mucus secreted by vermitid gastropods to trap particles is frequently in contact with coral reefs. This interaction can alter coral dimension by reducing coral rugosity (surface roughness), making the coral surface smoother and lowering the growth rate (Shima et al., 2013). Therefore, marine gastropods play an essential role in structuring coral communities and contributing to the ecological balance of coral reef ecosystems.

CHAPTER 3

METHODOLOGY

3.1 Description of study area

Terengganu had one of the longest sandy coastlines (244km) in Peninsular Malaysia and several offshore islands (McAfee, 2017). The marine park islands were represented by Pulau Perhentian, Pulau Redang, Pulau Kapas, Pulau Tenggol, Pulau Yu Besar and Pulau Yu Kecil. Meanwhile, Pulau Bidong was designated as a state park.

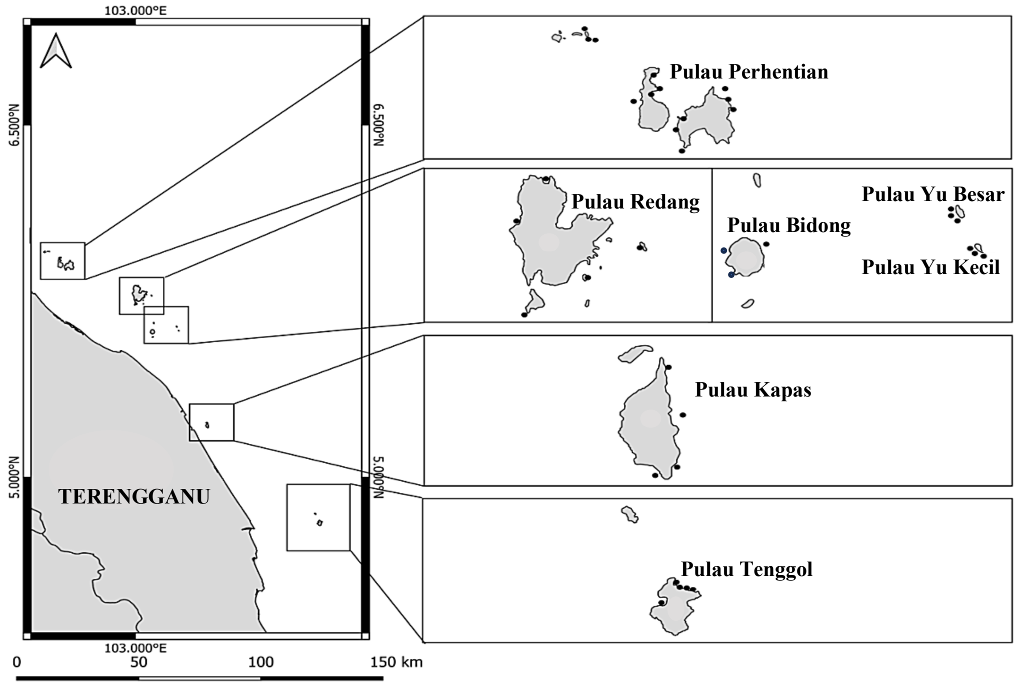

Figure 3.1 Map of Terengganu in Peninsular Malaysia showing the study area; Pulau Perhentian, Pulau Redang, Pulau Bidong, Pulau Yu Besar, Pulau Yu Kecil, Pulau Kapas and Pulau Tenggol (● = site).

Figure 3.2 Images of sampling sites taken from July to October 2020 (Source: Baharuddin et al. 2020).

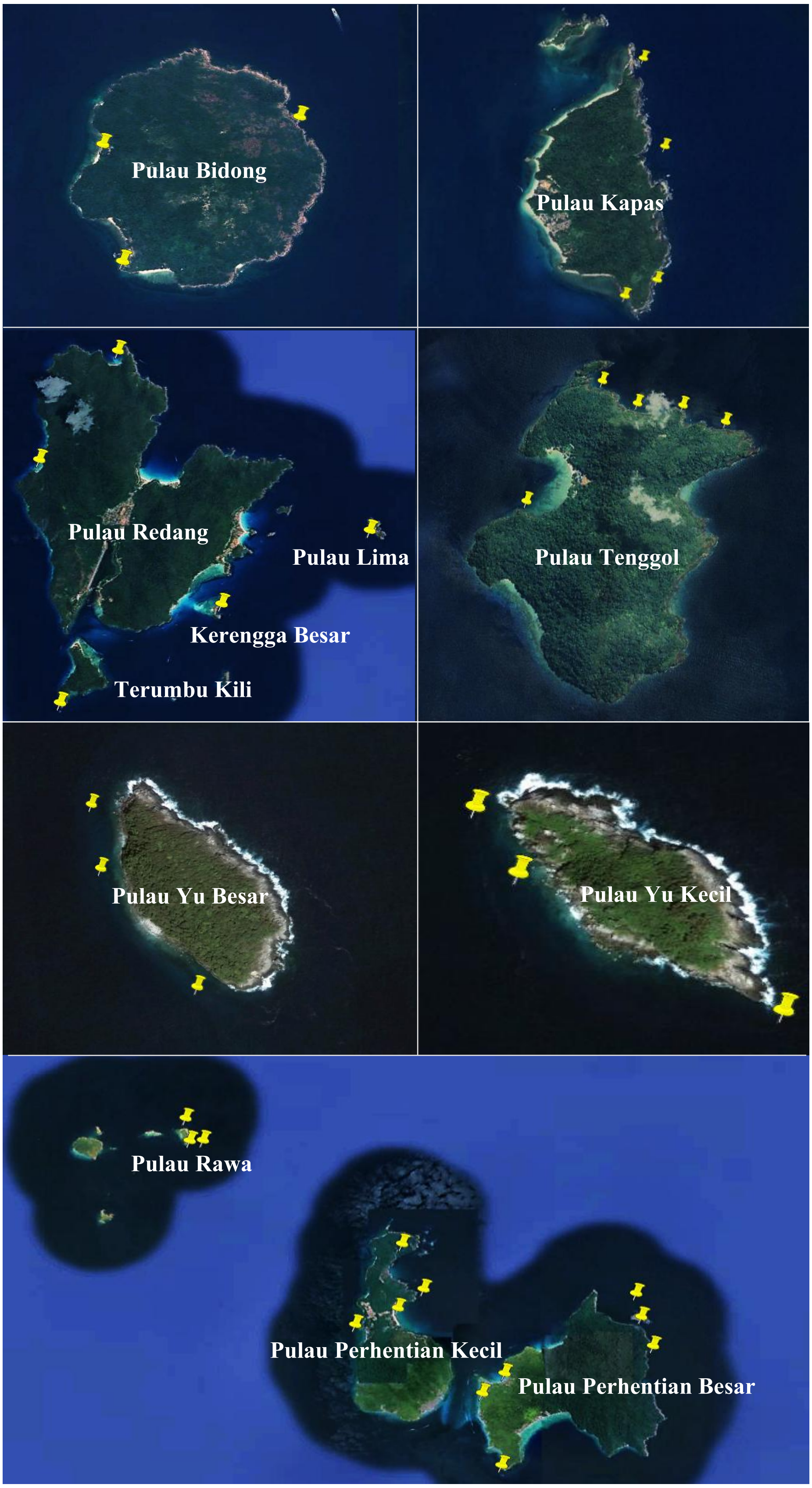

Figure 3.3 Aerial views of sampling studies in Terengganu marine protected islands (Source: Google Earth, 2025).

Pulau Bidong was a small island with an area of 1 km² and located off the east coast of Peninsular Malaysia in Terengganu. It was historically significant as a home to the Vietnamese boat people in the 1970s and 1980s. The island remained uninhabited since the repatriation of refugees in the late 1980s (Grismer et al., 2014). Although Pulau Bidong was not officially listed as a marine park, it was declared a national heritage site in Malaysia due to the abundance and richness of its benthic species. The waters surrounding the island supported a variety of coral life, from branching to massive coral reefs that hosted diverse fish communities. Most coral reefs around Pulau Bidong were dominated by branching, massive, tabulate and foliose corals (Firdaus et al., 2021).

Apart from that, Pulau Kapas was a small island located 4km offshore of Marang district, roughly 20 km south of Kuala Terengganu. It was declared a marine park in 1994. Fishing activities were prohibited within the one nautical mile boundary zone around Pulau Kapas as many nearby fishing households relied on commercial fish for their livelihood. The protected status helped to sustain healthy reef conditions, reduced destructive fishing practices and maintained marine biodiversity. The coral reefs surrounding this island were composed of diverse forms, including branching, massive and encrusting corals (Hong et al., 2020). These corals served as nurseries and breeding grounds for various marine organisms.

Furthermore, Pulau Redang was located approximately 45 km north-northeast of Kuala Terengganu and comprised a group of several islands. The island was gazetted as a marine park under the management of the DoFM (Razak et al. 2024). The marine park boundary was established by a line connecting points within two nautical miles of the coasts of Pulau Redang and several other smaller islands. This marine park status restricted harmful human activities and allowed marine life to survive. The coral reefs were dominated by an array of hard and soft corals, including *Acropora*, *Porites*, and *Montipora* species, which provided essential habitats for fish, molluscs and echinoderms (Bachok et al., 2020; Hong et al., 2020). Pulau Redang was also an important site for turtle conservation, making the island a focal area for conservation, scientific research and sustainable marine tourism (Salleh et al., 2021).

Meanwhile, Pulau Tenggol had been part of Terengganu Marine Park islands since 1994 and was located 30 km from Dungun off the east coast of Terengganu. The island had no permanent local populations due to lack of electricity infrastructure, limited groundwater supplies and the absence of centralised sewage treatment. The harsh environmental conditions around Pulau Tenggol, including strong currents and waves, allowed only professional SCUBA divers to properly assess the island's conditions. These hydrodynamic forces contributed to high water quality and influenced the distribution of coral assemblage, including *Porites* species (MacNeil et al., 2019). Pulau Tenggol also functioned as an important foraging and transient habitat for migratory species such as whale sharks (Anandhi, 2025).

In addition, Pulau Yu Besar and Pulau Yu Kecil were small rocky islands designated as marine parks, bringing the total number of marine park islands in Peninsular Malaysia to 42. The coral reefs around these islands had a moderately high level of Nutrient Indicator Algae (NIA), indicating elevated nutrient levels that contributed to increased algae growth in the surrounding waters (Reef Check Malaysia, 2020). The substrates around Pulau Yu Besar and Pulau Yu Kecil were mainly composed of branching corals, coral rubbles and rocks, providing essential shelter for cryptic species (Bachok et al., 2021).

Lastly, Pulau Perhentian, known as one of the largest marine parks in Peninsular Malaysia, had a diverse coral ecosystem and was an ideal destination for tourists (Jaafar & Maideen, 2012). The island was located 21 km from Terengganu and the Department of Fisheries Malaysia (DoFM) protected the marine ecosystem by designating it as a marine protected area in Pulau Perhentian in 1983. Pulau Perhentian was later officially declared a marine park in 1994 under the Marine Park Malaysia Order 1994. The order established a no-fishing zone extending 3.70 km from the lowest water level mark of island. This protection allowed the coral reef ecosystems to flourish, with a high diversity of coral species such as branching and foliose types that supported a wide array of marine life (Safuan et al., 2022).

3.2 Field sampling and laboratory analysis

3.2.1 Fieldwork

The fieldworks were carried out from July until October 2020. The SCUBA divers surveyed a 50 m x 10 m transect line within coral reef areas at depths ranging from approximately 3-5 m (shallow) to 10-12 m (deep), depending on coral conditions. These surveys were carried out at designated sampling sites across different islands using a non-destructive sampling approach. A one dive-one station ratio was applied to ensure consistency of sampling effort and reduce diver fatigue-related bias (Couch et al., 2021; Burns et al., 2025). At each study site, a quadrat of 0.0625 m^2 was used to quantify gastropods abundance within the transect line in the coral reef area. Gastropods specifically inhabiting branching coral (e.g. *Acropor*a spp.) were systematically collected along each transect based on the method by McClanahan (1997). The complex structure of branching corals provided holes and crevices within the reef where gastropods could seek protection from predation (Seinor et al., 2020). These methods were suitably adjusted to align with the unique characteristics of the study area. A series of underwater photographs were taken to document the presence or absence of coral reef gastropods and their coral prey. The gastropods observed at the site were carefully collected using forceps to minimise disturbance to the coral colonies. Subsequently, these collected specimens were placed in plastic bags and stored in an ice chest before being transferred to a freezer set at -20ºC for further laboratory analysis.

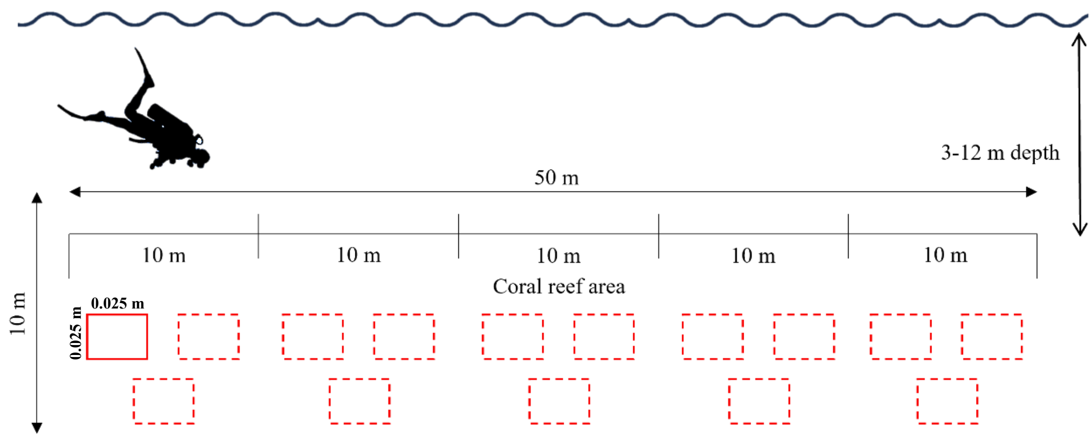

Figure 3.4 The layout of a transect line and the quadrat position at each sampling site.

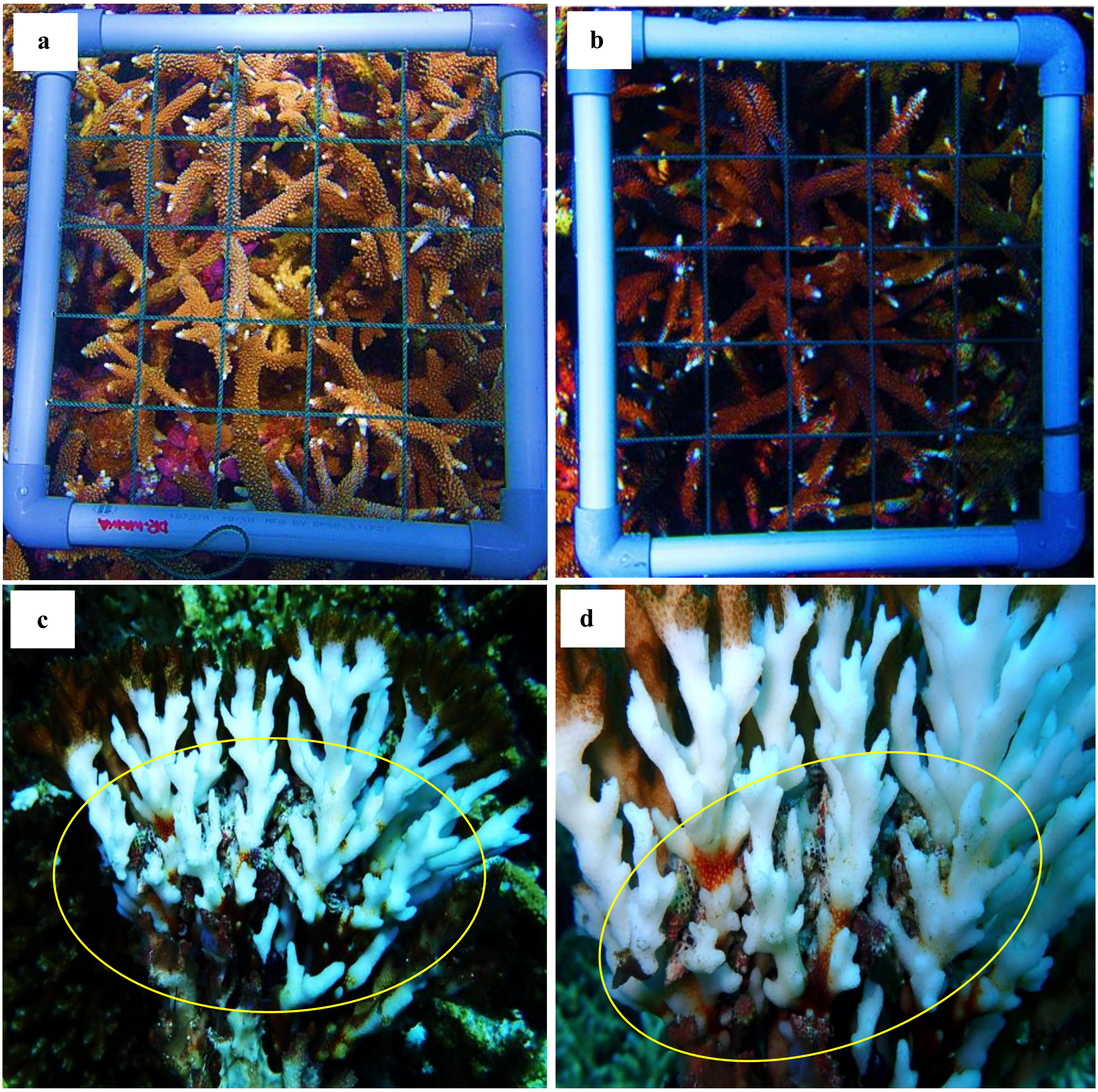

Figure 3.5 The layout of a transect line and the quadrat position at each sampling site; a: b) the positions of the quadrat on *Acropora* spp. and c: d) the aggregations of gastropods within corals.

Table 3.1 Environmental, coral reefs and microhabitat characteristics of sampling stations. The number of sampling sites, dives and date of collection at each sampling station were shown.

Station	Environmental, coral and microhabitat characteristics	Number of sampling sites	Number of divers	Number of dives	Duration of diving (one diver)	Date of collection
Pulau Redang	Less wavy and windy, moderately dense *Acropora,* presence of *Pocillopora* and *Montipora* corals, have boulders, coral rubbles and dense macroalgae layer	5	2	5	30 minutes	16 - 19 July, 2020
Pulau Perhentian	Less wavy and windy, low visibility due to high water turbidity, dense *Acropora* and *Porites* corals, have small boulders, many coral rubbles and macroalgae layer on coral surface	13	2	13	30 minutes	23 - 28 October, 2020
Pulau Bidong	Wavy and rough seas, less dense of *Acropora,* many dead corals and small boulders	3	2	3	30 minutes	6 - 7 September, 2020
Pulau Kapas	Wavy and windy, low visibility due to water turbidity, dense *Acropora* corals but many dead corals, have boulders, coral rubbles and crutose coralline algae on coral surface	4	2	4	30 minutes	22 - 23 September, 2020
Pulau Yu Besar	Wavy and rough seas, moderately dense *Acropora* corals and have coral rubbles	3	2	3	30 minutes	27 - 28 September, 2020
Pulau Yu Kecil	Wavy and rough seas, dense *Acropora* corals, have a thin layer of macroalgae and coral rubbles	3	2	3	30 minutes	29 - 30 September, 2020
Pulau Tenggol	Very wavy and high sea currents, low visibility due to water turbidity, dense *Acropora* and *Porites* corals, have coral rubbles and dense macroalgae layer on coral surface	5	2	5	30 minutes	10 - 13 October, 2020

The variation in sampling efforts among the islands was influenced by site accessibility as well as covering various directions from north, east, south and west for each of the islands. However, some sites cannot be accessed and sampled due to severe environmental conditions. Assumptions about the occurrence of coral reef gastropods may have been limited by several factors including inaccessible study areas, the restricted distribution of gastropods due to coral type preferences and challenges collecting gastropods in structurally complex habitats (Krebs, 1978). In addition, several challenges arose during sampling, including rough seas and strong currents that limited the diving schedule and prevented some sites from being assessed safely. Although the non-destructive sampling method minimised disturbances to coral reefs, it required careful handling techniques, which increased the time needed for gastropod collection. Some gastropods hid in crevices and within substrate layers, making them difficult to locate without disturbing coral reefs. Poor underwater visibility due to water turbidity caused misidentification of gastropods during field observation, often leading to the repeated collection of the same species.

3.2.2 Gastropods identification

To elucidate the external morphology of gastropods, the shells of each collected specimen were meticulously cleansed to remove extraneous sand and attached symbionts. Subsequently, the gastropods were identified based on the shape, colour and ornamentation of the shell with the aid of available literature's identification keys and online resources including Abbott & Dance (2000), Wells et al. (2021) and Hardy's Internet Guide to Marine Gastropod (2021). The World Register of Marine Species (WoRMs, 2021) was also used to verify the currently accepted names of the species at the lowest possible taxonomic level.

3.2.3 Shell metric and biomass

The shell length (mm) was obtained using a digital calliper (0-200 mm) for the nearest two decimal places. Each gastropod's wet weight (g) was recorded by placing it on a piece of pre-weighted aluminium tin foil using an electronic weighing balance (RADWAG-0.01 g). All gastropods in the aluminium foil were dried in an oven (BINDER-100 L) at 65ºC for five days to determine dry weight. The dried samples were reweighed on days three, four and five to ensure the consistency of whole-body dry weight (g). After drying, all gastropods were put in weighted and labelled crucible jars and transferred to a muffle furnace (CARBOLITE-32 L). The furnace combusted the gastropods at 450ºC for four hours. Afterwards, the gastropods were removed from the furnace and left to cool. The gastropods were then carefully removed from the crucible jars, and the shells were gently tapped to remove any ash residue. The ash-free dry weight (g) of individual snails was recorded using an electronic weighing balance and the condition index (*CI*) was calculated as the ratio of:

$$CI = \text{Dry flesh weight (g)}/\text{Dry shell weight (g)}$$

3.2.4 Feeding guilds

The identified gastropods were grouped into specific feeding guilds based on previous studies, including Saponari et al. (2021); Gautrand et al. (2023) for corallivorous, Wright et al. (2018); Soekendarsi (2019); Ghatpande et al. (2024) for carnivorous and Sun & Zhang (2014); Soekendarsi (2019); Zainuddin et al. (2024) for herbivorous.

The percentage of coral reef gastropod feeding guilds was analysed into two categories: among islands and within islands. For the among islands category, the total number of individuals (categorised by feeding guilds) on a given island was divided by the total number of individuals (categorised by feeding guilds) across all islands. Meanwhile for the percentage of gastropods feeding guilds within islands, the total number of individuals (categorised by feeding guilds) on each island was divided by the total number of individuals (regardless of feeding guilds) across all islands.

3.3 Data Analysis

3.3.1 Diversity assessment

Previous researchers have used the Paleontological Statistical (PAST) software to determine ecological indices in gastropod communities in Terengganu (Baharuddin & Zakaria, 2018; Basir et al., 2022). The present study used PAST software version 3.0 to determine the following ecological indices: Shannon's Diversity Index, Simpson's Diversity Index, Margalef's Index, Menhinick's Index, Pioleu's Evenness Index and Equitability's Index.

i) Shannon's Diversity Index

Shannon diversity index was one of the simplest and commonly used to measure the alpha diversity of the ecological community in the study area. When the index value was high, the area was considered to have high species richness. Magurran (2004) described that Shannon index values range from 0 to 5, where a value below 1.5 indicated low diversity, while values between 4 and 5 showed exceptionally high diversity. More commonly, the observed value of this index falls between 1.5 to 3.5. The formula was calculated as follows (Hammer et al., 2001):

$$H' = -\sum_{i-1}^{s} pi \, lnpi$$

Where,

H'=Shannon diversity index

s=Number of species represented in the sample

pi=Number of individuals of species ith

ii) Simpson's Diversity Index

The Simpson index was often used to measure habitat biodiversity. It calculated the probability that two individuals of the same species were randomly selected from an infinitely large population. Simpson diversity index (*D*) was calculated as below:

$$D= 1 - \sum(pi)^2$$

Where,

D=Dominance index

pi=Number of individuals of species ith

According to Magurran (2004), Simpson index showed an inverse relationship with diversity as higher *D* values corresponded to decreasing diversity values. The index was heavily weighted towards the most abundant species in the community and less sensitive to species richness.

iii) Margalef's Index

The Margalef index (*Ma*) provided a measure of species richness within an ecological community and this concept stated that a higher value of *Ma* indicated habitats with greater species richness (Hammer et al., 2001). The formula was calculated as:

Ma=(s-1)/ In N

Where,

s=Number of species represented in the sample

N=Total number of individuals of all species

iv) Menhinick's Index

Menhinick index (*Me*) measured species richness, which indicated the number of species found within a defined area. The formula was as follows (Hammer et al., 2001).

$$Me = s/\sqrt{N}$$

Where,

s=Number of species represented in the sample

N=Total number of individuals of all species

iv) Pielou's Evenness Index

Pielou evenness index (J') also measured the assemblage's uniformity or evenness. The formula calculated was as follows:

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

Where,

J'=Pielou evenness index

H'=Shannon diversity index

H'max=Natural logarithm of species

iv) Equitability's Index

The Equitability index (Ep) measured the equality of species distribution by assessing the evenness of species abundance within a community. The formula was calculated as follows:

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

Where,

H'=Shannon diversity index

S=Number of species recorded

As stated above, both indices' values range from 0 to 1, where 0 represented no equality and 1 represented complete equality. The index value approaching 1 signified that the individual species were relatively similar, while the index value closer to 0 indicates more variation in species.

Table 3.2 The evenness criteria following Krebs (1972).

E-value	**Condition of community structures**	**Category**
>0.81	Very equally	Very good
0.61-0.80	More equally	Good
0.41-0.60	Equally	Medium
0.21-0.40	Fairly equally	Poor
<0.2	Not equally	Very poor

Meanwhile, a rarefaction curve was used to estimate the species richness of a community based on a given sampling effort, which allowed researchers to compare species diversity between different study sites.

3.3.2 Species abundance and distribution

To determine the Species Abundance Distribution (SAD) of coral reef gastropods, a Rank Abundance Curve (RAC) was plotted using Microsoft Excel based on abundance of gastropods. To construct the RAC, each species was ranked from most abundant to least abundant. The partitioning between common, moderate and rare species was constructed. The rare species typically comprised of singletons and doubletons (Magurran, 2004).

3.3.3 Shell metric and biomass

A one-way ANOVA was a hypothesis test to compare independent variables such as shell length and biomass for similar gastropod species between Terengganu marine protected islands. Analysis was done by using transformed data ($\log_{10}$). All data was transformed before analysis due to the uneven distribution of data. Post hoc Tukey was commonly used to identify which pair of means in a set of groups were significantly different. The statistical difference was set at $p<0.05$.

3.3.4 Coral reef condition

The percentage of live coral cover was used to categorise the reef condition by following the ASEAN-Australia Living Coastal Resource Project as ‘excellent’ (>75%), ‘good’ (<75% and >50%), ‘fair’ (<50% and >25%) and ‘poor’ (<25%) (Chou et al., 1994; Reef Check Malaysia, 2020).

Table 3.3 Category of coral reefs based on percentage of live coral cover (adapted from Rizmaadi et al., 2018).

	Category	Percentage (%)
Bad	Poor	0-24.9
	Fair	25-49.9
Good	Good	50-74.9
	Excellent	75-100

CHAPTER 4

RESULTS

4.1 Diversity and distribution of coral reef gastropods

A total of 704 individual coral reef gastropods from nine species were recorded in Terengganu Marine Protected islands (Table 4.1). The species were *Astralium rhodostomum, Cerithium columna, Cerithium coralium, Coralliophila violacea, Drupella cornus, Drupella rugosa, Morula spinosa*, *Arakawania marginalba* and *Arakawania ceylonica.* The most prevalent species found were *D. rugosa* and *A. marginalba* with a total of 479 and 121 individuals, respectively.

Among the study sites, the highest number of gastropods was recorded at PPH with 210 individuals, followed by PRD (177) and PBD (111) (Table 4.1). However, the lowest number of individuals was recorded in PYB with only 26 individuals. *Frequency of Incidence (FoI)* refers to the proportion of the sampling location where a species is found. The *FoI* of 100 % for both *D. rugosa* and *A. marginalba* indicated that the species were found at all seven study sites. The lowest *FoI* was recorded by *A. rhodostomum*, *C. violacea*, *C. coralium* and *C. columna* with 14% only.

Table 4.1 Subclass, family and species of coral reef gastropods in Terengganu marine protected islands. The total number of individuals is shown (PBD=Pulau Bidong, PKS=Pulau Kapas, PPH=Pulau Perhentian, PRD=Pulau Redang, PTG=Pulau Tenggol, PYB=Pulau Yu Besar and PYK=Pulau Yu Kecil), (CA=Carnivorous, CO=Corallivorous and HE=Herbivorous), (*FoI=Frequency of Incidence*) and '-'indicate none of gastropods present in area.

Subclass	Family	Species	Feeding mode	Study sites							Total of individuals (n)	Rank abundance	*FoI* (%)
				PBD	PKS	PPH	PRD	PTG	PYB	PYK			
Caenogastropoda	Muricidae	*Drupella rugosa* (Born, 1778)	CO	97	38	140	112	35	18	39	479	1	100
		Arakawania marginalba (Blainville, 1832)	CA	2	14	42	43	4	5	11	121	2	100
		Morula spinosa (H. Adams & A.Adams, 1853)	CA	6	4	23	12	-	-	17	62	3	71
		Drupella cornus (Röding, 1798)	CO	6	-	4	-	8	2	3	23	4	71
Vetigastropoda	Turbinidae	*Astralium rhodostomum* Lamarck, 1822	HE	-	-	-	10	-	-	-	10	5	14
Caenogastropoda	Muricidae	*Coralliophila violacea* (Kiener, 1836)	CO	-	-	-	-	5	-	-	5	6	14
		Arakawania ceylonica (Dall, 1923)	CA	-	-	-	-	-	1	1	2	7	29
	Ceriithidae	*Cerithium coralium* (Kiener, 1841)	HE	-	-	-	-	1	-	-	1	8	14
		Cerithium columna (G.B. Sowerby I, 1834)	HE	-	-	1	-	-	-	-	1	9	14
Total of individuals (n)				111	56	210	177	53	26	71	704		
Total of species				4	3	5	4	5	4	5			

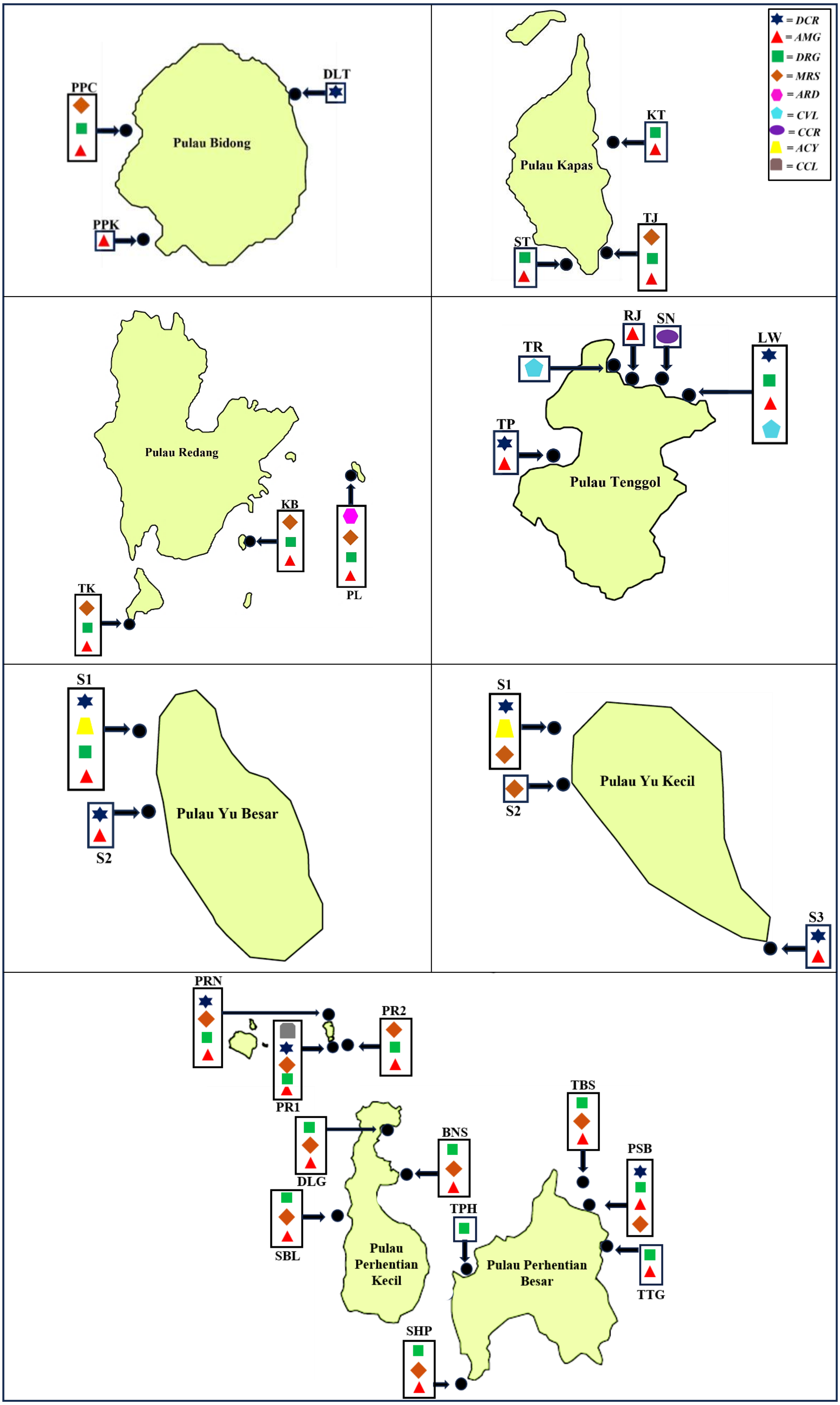

Figure 4.1. Map of species distribution in Terengganu marine protected islands.

4.1.1 Systematics and descriptions of coral reef gastropods

Phylum Mollusca

Class Gastropoda Cuvier, 1975

Family Turbinidae Rafinesque, 1815

Genus *Astralium* Link, 1807

Type species. *Astralium rhodostomum* (Lamarck, 1822)

Description. Shell has flat-sided whorls with projecting spines along the lower edges. Colour is white and creamy. Protoconch is eroded but appears whitish. Aperture has a shiny circular white shape. Ovate operculum with mauve tint and pinkish colour. Base is flat and glossy operculum is partially eroded.

Distribution. The Turbinidae family is primarily distributed in the Indo-West Pacific and least found in the Eastern Pacific and Western Atlantic. *Astralium rhodostomum* is also recorded in Terengganu, Malaysia (Zainuddin et al., 2024).

Occurrence. Pulau Redang

Feeding mode. *Astralium rhodostomum* is an herbivorous gastropod that feeds on algae on the coral surfaces (Meyer et al., 2005).

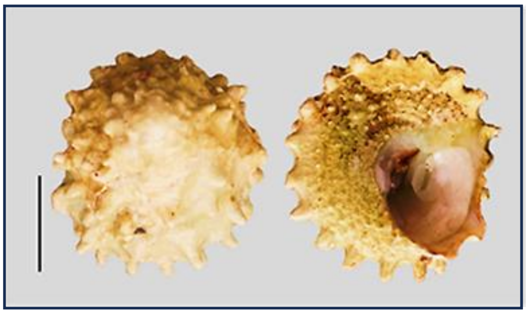

Figure 4.2 *Astralium rhodostomum.* SL: 22 mm and scale bar: 10 mm

Family Cerithiidae J. Fleming, 1822

Genus *Cerithium,* Bruguière, 1789

Type species. *Cerithium columna* G. B. Sowerby I, 1834

Description. Shell is orange-brown with some creamy colour, has a nodulose sculpture and short siphonal canal. Aperture is dark brown. Crenulated lip curves to cross the siphonal canal at a 90-degree angle. Operculum is absent during sampling.

Distribution. *Cerithium columna* is an herbivorous snail species that inhabits seagrass and grit beds at the intertidal zone and upper subtidal level of the Indo-Pacific region.

Occurrence. Pulau Perhentian

Feeding mode. *Cerithium columna* is an herbivorous gastropod that feeds on algae (Sun & Zhang, 2014).

Figure 4.3 *Cerithium columna.* SL: 21 mm and scale bar: 10 mm.

Type species. *Cerithium coralium* Kiener, 1841

Description. Shell has a slender shape with straight-sided whorls. Shell is sculptured with dark brown spiral line on a brownish-orange body whorl. White patches on body whorl. Siphonal canal is short and broad. Smooth outer lip has posterior sinuses. Aperture is fusiform. Operculum is absent during the sampling period.

Distribution. *Cerithium coralium* is commonly found in the Indo-Pacific region, including the Philippines, China, Indonesia and Malaysia (Ilias et al., 2021). It typically inhabits mangrove areas and the upper zone of intertidal areas.

Occurrence. Pulau Tenggol

Feeding mode. *Cerithium coralium* is an herbivorous gastropod that feeds on algae (Sun & Zhang, 2014).

Figure 4.4 *Cerithium coralium.* SL: 45 mm and scale bar: 10 mm.

Family Muricidae Rafinesque, 1815

Genus *Coralliophila* H. Adams & A. Adams, 1853

Type species. *Coralliophila violacea* (Kiener, 1836)

Description. Shell is rounded with outer surfaces encrusted with calcareous algae on body. Siphonal canal is short. Aperture is bright violet. Body whorl displays fine spiral lines. Operculum is embedded within the shell.

Distribution. *Coralliophila violacea* is distributed across the tropical Indo-Pacific region. It can be found in Southeast Asia countries such as Malaysia, Indonesia and the Philippines (Baharuddin et al., 2020; Simmonds et al., 2020).

Occurrence. Pulau Tenggol

Feeding mode. *Coralliophila violacea* is a corallivorous gastropod that feeds on coral, especially *Porites* spp. (Gautrand et al., 2023).

Figure 4.5 *Coralliophila violacea*. SL: 18 mm and scale bar: 10 mm.

Genus *Drupella* Rafinesque, 1815

Type species. *Drupella cornus* (Röding, 1798)

Description. Shell has prominent rows of spiny nodules and numerous smaller pines. Shell colour is greenish brown with white patches. Surface is rough, depending on the degree of algae. Operculum is dark brown with a creamy colour near edges. Aperture is creamy with darker tones near inner edge. Outer lip is smooth.

Distribution. *Drupella cornus* is commonly distributed in the Indo-Pacific province. It occurs in the Red Sea (Mbije et al., 2019), Singapore (Samsuri et al., 2018) and Ningaloo Reef, Australia (Haslam et al., 2025).

Occurrence. Pulau Perhentian, Pulau Tenggol, Pulau Bidong, Pulau Yu Besar and Pulau Yu Kecil.

Feeding mode. *Drupella cornus* is a corallivorous gastropod that feeds on coral reefs, mainly the *Acropora* and *Pocillopora* genera (Bessey et al., 2018).

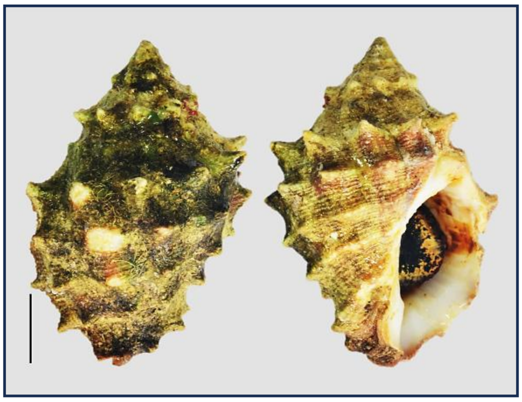

Figure 4.6 *Drupella cornus.* SL: 44 mm and scale bar: 10 mm

Type species. *Drupella rugosa* (Born, 1778)

Description. Shell has a scabrous surface and moderately high spire. Shell is light greenish with a reddish spot. Body whorl with spiral rows of prominent tubercles separated by axial rib with fine granules. Aperture is dark reddish with a narrow opening. Outer lip has six lateral denticles. Operculum is ovulated and dark brown.

Distribution. *Drupella rugosa* is found in Indo-Pacific waters such as East Africa, Southeast and Northeast Asia. *Drupella rugosa* also recorded in Kenya, Western Australia, Hong Kong, the Red Sea, India, Thailand and Malaysia (Baharuddin et al., 2017; Saponari et al., 2021).

Occurrence. Pulau Redang, Pulau Perhentian, Pulau Tenggol, Pulau Kapas, Pulau Bidong, Pulau Yu Besar and Pulau Yu Kecil.

Feeding mode. *Drupella rugosa* is a corallivorous gastropod that feeds on corals, mainly *Acropora* spp. (Sam et al., 2017).

Figure 4.7 *Drupella rugosa.* SL: 29 mm and scale bar: 10 mm

Genus *Morula* Schumacher, 1817

Type species. *Morula spinosa* (H. Adams & A. Adams, 1853)

Description. Shell has an oval shape with a pointed apex. It has several spines along the edges. Colour is reddish-orange with cream patches. Aperture is elongated and narrow with a deep blue interior. Operculum is oval but embedded inside the shell.

Distribution. *Morula spinosa* is typically found in the Indo-Pacific: East Africa, Southeast and Northeast Asia. *Morula spinosa* is distributed in the Philippines, Japan and Korea. It also occurs in Terengganu, Malaysia (Baharuddin et al., 2020; Zainuddin et al., 2024).

Occurrence. Pulau Redang, Pulau Perhentian, Pulau Kapas, Pulau Bidong, Pulau Yu Besar and Pulau Yu Kecil.

Feeding mode. *Morula spinosa* is a carnivorous gastropod that also feeds on corals and small gastropods (Zainuddin et al., 2024).

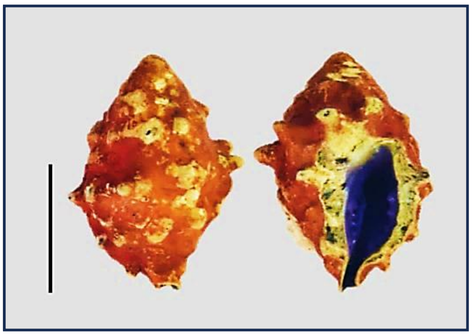

Figure 4.8 *Morula spinosa.* SL: 14 mm and scale bar: 10 mm.

Genus *Arakawania* Ponting, 2024

Type species. *Arakawania marginalba* (Blainville, 1832)

Note. Formerly known as *Tenguella marginalba,* however the species name was recently updated to *Arakawania marginalba* on 14 October 2024 by Philippe Bouchet.

Description. Shell is conical and fusiform with a creamy pointed apex. Shell has dark purple rows on light brown body whorl. Aperture is ovate, bright reddish-pink and has narrow opening. Operculum is dark tone. Outer lip is curved with eight white denticles.

Distribution. This species is a murex snail distributed around the north-east coast of Australia, the Philippines and Malaysia (Baharuddin et al., 2019). It is commonly found at the edge of the pools, crevices and low shore habitats.

Occurrence. Pulau Redang, Pulau Perhentian, Pulau Tenggol, Pulau Kapas and Pulau Yu Kecil.

Feeding mode. The species is a carnivorous gastropod that feeds on barnacles, limpets and oysters (Wright et al., 2018).

Figure 4.9 *Arakawania marginalba.* SL: 19 mm and scale bar: 10 mm.

Type species. *Arakawania ceylonica* (Dall, 1923)

Note. Formerly known as *Tenguella ceylonica,* however the species name was recently updated to *Arakawania ceylonica* on 14 October 2024 by Philippe Bouchet.

Description. Shell is encrusted with light green calcareous deposits with reddish-pink spots. Aperture is ovate and dark brown. Operculum is brown.

Distribution. This species is usually distributed in countries such as India and the Philippines (Houart et al., 2017). In Terengganu, the species can also be found in two marine park islands.

Occurrence. Pulau Yu Besar and Pulau Yu Kecil

Feeding mode. The species is a carnivorous gastropod that feeds on molluscs, barnacles and other varieties of prey (Ghatpande et al., 2024).

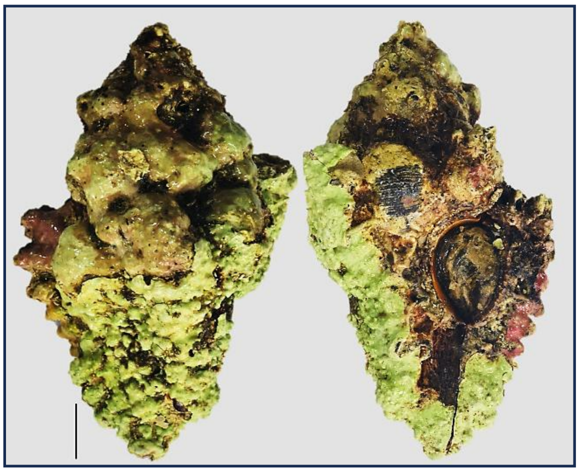

Figure 4.10 *Arakawania ceylonica.* SL: 74 mm and scale bar: 10 mm

4.2 Diversity, distribution and abundance among islands

4.2.1 Diversity assessment

Table 4.2 showed the values of diversity indices in Terengganu marine protected islands. Shannon diversity index (*H'*) was lowest in Pulau Bidong (0.506) and the highest in Pulau Yu Kecil (1.154). Simpson diversity index (*D*) indicated a low diversity index value in which Pulau Bidong obtained the lowest (0.230) while Pulau Yu Kecil had the highest value with 0.615 (Table 4.2). Margalef and Menhinick indices showed variation scores that indicated species richness in Terengganu marine protected islands. The lowest and highest values for the Margalef index were in Pulau Kapas (*Ma*=0.497) and Pulau Yu Kecil (*Ma*=1.007). Pulau Redang and Pulau Yu Kecil obtained the lowest and highest values for the Menhinick index with *Me*=0.301 and *Me*=0.785, respectively (Table 4.2). The evenness (J') and equitability (Ep) also indicate low homogeneity and pattern distribution of species, where Pulau Bidong had the lowest with J'=0.365 and Ep=0.415 while the highest value of homogeneity in Pulau Kapas (J'=0.741) and (Ep=0.727), respectively (Table 4.2).

Table 4.2 The diversity assessment varied in Pulau Bidong (PBD), Pulau Kapas (PKS), Pulau Perhentian (PPH), Pulau Redang (PRD), Pulau Tenggol (PTG), Pulau Yu Besar (PYB) and Pulau Yu Kecil (PYK). (*H'*=Shannon diversity index, *D*=Simpson diversity index, *Ma*=Margalef index, *Me*=Menhinick index, J'=Evenness index and Ep=Equitability index).

Study sites	*H'*	*D*	*Ma*	*Me*	J'	Ep
PBD	0.506	0.230	0.637	0.380	0.365	0.415
PKS	0.798	0.472	0.497	0.401	0.741	0.727
PPH	0.935	0.497	0.748	0.345	0.510	0.581
PRD	0.978	0.533	0.580	0.301	0.665	0.706
PTG	1.052	0.526	0.938	0.687	0.573	0.654
PYB	0.894	0.476	0.921	0.593	0.645	0.611
PYK	1.154	0.615	1.007	0.785	0.717	0.634

4.2.2 Diversity comparison

Based on the rarefaction curve, Pulau Tenggol, Pulau Yu Besar and Pulau Yu Kecil gradually increased species richness during early sampling (Figure 4.11). The curves of these three islands did not reach an asymptote, indicating insufficient data due to the low sampling area coverage. The curve might reach equilibrium as the species of gastropods increases if the sampling continues and more areas are covered (Jurkiewicz-Karnkowska, 2009). However, Pulau Redang, Pulau Kapas and Pulau Bidong showed an asymptote, indicating that nearly all the available species had been found. Pulau Perhentian was experiencing rapid increases in reaching an asymptote level.

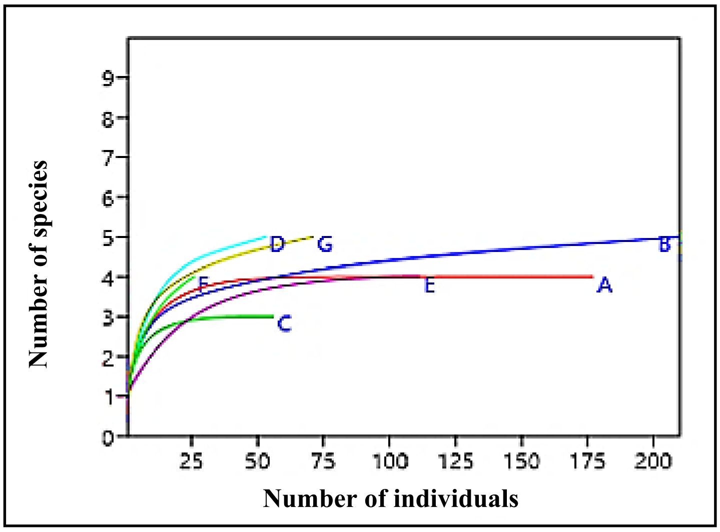

Figure 4.11 Rarefaction curve comparing species diversity between study sites. A=Pulau Redang; B=Pulau Perhentian; C=Pulau Kapas; D=Pulau Tenggol; E=Pulau Bidong; F=Pulau Yu Besar and G=Pulau Yu Kecil.

4.2.3 Species abundance and distribution

Figure 4.12 showed the species abundance distribution of coral reef gastropods sampled in each island of this study. The most abundant species was *D. rugosa* for each island (Figure 4.12). *Arakawania marginalba* was the second most dominant species in Pulau Perhentian, Pulau Redang and Pulau Kapas, followed by *M. spinosa*. *Drupella rugosa* was categorised as a common species. Meanwhile, *A. ceylonica*, *C. coralium* and *C. columna* were classified as rare species comprising singletons and doubletons. Species not categorised as dominant or rare were considered intermediate species.

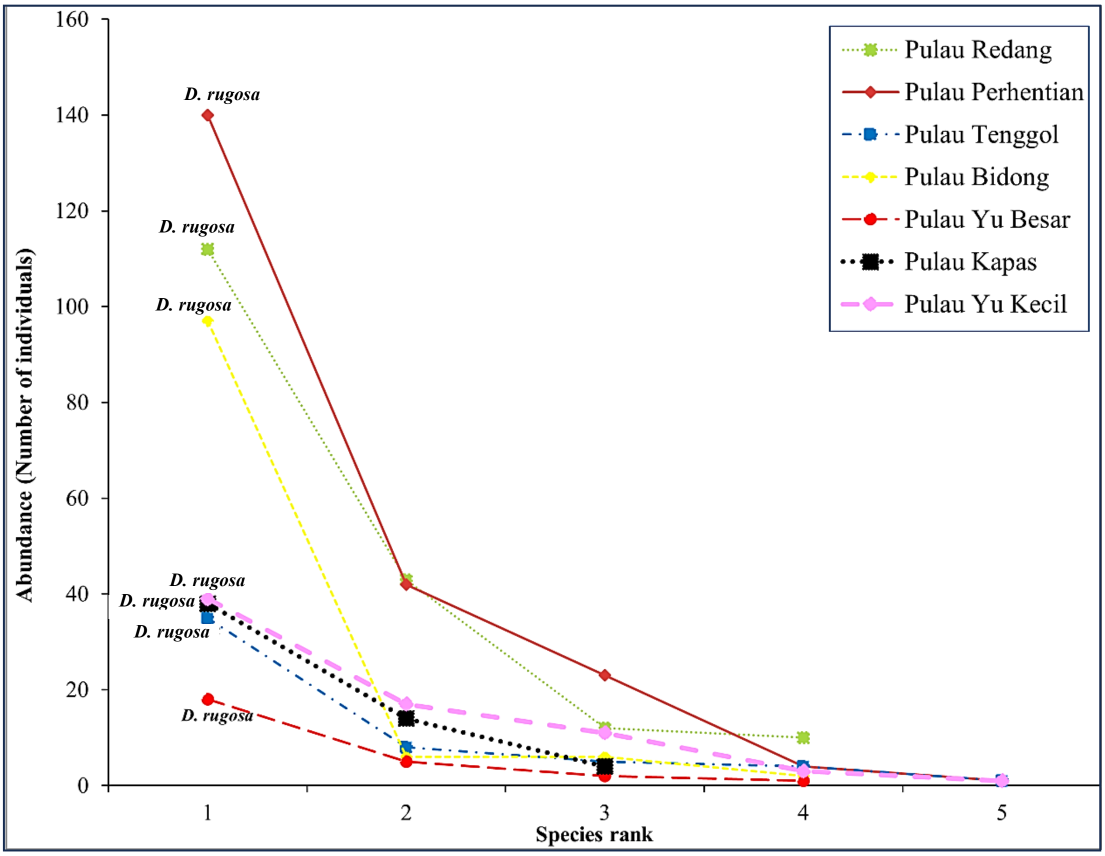

Figure 4.12 Rank abundance curve of gastropods collected at coral reefs in Terengganu marine protected islands, where abundance is plotted against species rank from most to least abundant.

4.3 Diversity, distribution and abundance within islands

4.3.1 Pulau Bidong

Table 4.3 showed the presence of 111 individuals of four gastropod species at study sites in Pulau Bidong. The species were *D. rugosa, D. cornus, M. spinosa* and *A. marginalba. Drupella rugosa* had the most individuals (97). Meanwhile, both *D. cornus* and *M. spinosa* had six individuals. In addition, *A. marginalba* contributed the smallest number as only two individuals were found in PPC. PPC recorded the highest number with three species and 65 individuals compared to PPK (one species and 40 individuals) and DLT (one species and six individuals), respectively. Among these three sites, *D. rugosa* recorded the most abundant individuals with 57 in PPC and 40 in PPK. The *FoI* for *D. rugosa* was 67% as the species occurred at two sites on Pulau Bidong. *Drupella cornus, Morula spinosa* and *Arakawania marginalba* were only found in one site and contributed 33 % of *FoI.*

Table 4.3 Abundance of coral reef gastropods in Pulau Bidong according to subclass, family and species between study sites. The total number of individuals and *Frequency of Incidence* are shown (DLT=Dinding Laut, PPK=Pantai Pasir Pengkalan and PPC=Pantai Pasir Cina). n=total no of individual, *FoI*=*Frequency of Incidence* and - =none of gastropod present.

Subclass	**Family**	**Species**	**Study sites**			**Total of individuals (n)**	***FoI*(%)**
			DLT	**PPK**	**PPC**		
Caenogastropoda	Muricidae	*Morula spinosa*	-	-	6	6	33
		Drupella cornus	6	-	-	6	33
		Arakawania marginalba	-	-	2	2	33
		Drupella rugosa	-	40	57	97	67
Total of individuals			6	40	65	111	
Total species			1	1	3	5	

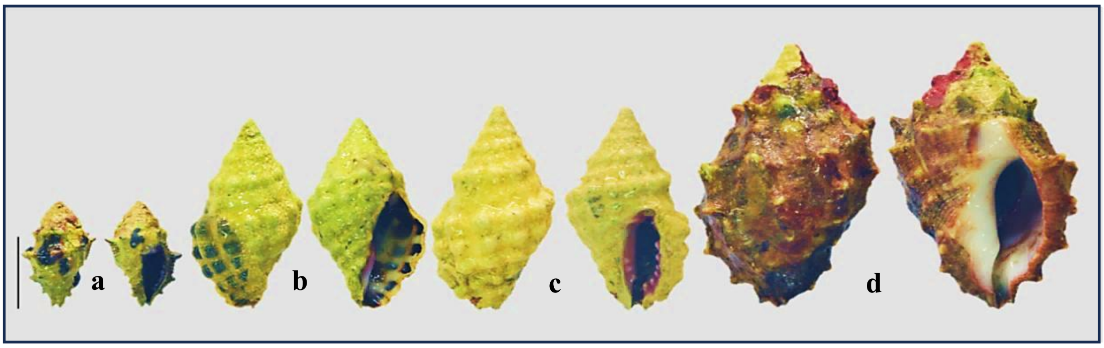

Figure 4.13 Coral reef gastropods of Muricidae in Pulau Bidong. a) *Morula spinosa*; b) *Arakawania marginalba*; c) *Drupella rugosa*; d) *Drupella cornus*. All specimens were photographed in apertural (left) and abapertural (right) views. Scale bar: 10 mm.

In Pulau Bidong, the higher values of the Shannon and Simpson indices were found in PPC with *H'*=0.442 and *D*=0.222 (Table 4.4). The lowest values for both diversity indices were recorded in DLT and PPK with zero. The zero value indicated no diversity in DLT and PPK as only one species could be found. For the Menhinick index, DLT contributed a higher value with *Me*=0.408. Meanwhile, PPC gave a greater value for the Margalef index, *Ma*=0.479 (Table 4.4). The Evenness Index (J') recorded variation in values with the highest values recorded in DLT and PPK. In contrast, the lowest value was recorded at PPC with J'=0.519. The Equitability Index was only recorded at PPC with Ep=0.403.

Table 4.4 The diversity assessment of coral reef gastropods in Pulau Bidong (DLT=Dinding Laut, PPK=Pantai Pasir Pengkalan and PPC=Pantai Pasir Cina) and (*H'*=Shannon's diversity index, *D*=Simpson's diversity index, *Me*=Menhinick index, *Ma*=Margalef index, J'=Evenness index and Ep=Equitability index).

Study sites	***H'***	***D***	***Me***	***Ma***	**J'**	**Ep**
DLT	0	0	0.408	0	1	-
PPK	0	0	0.158	0	1	-
PPC	0.442	0.222	0.372	0.479	0.519	0.403

4.3.2 Pulau Kapas

Table 4.5 showed that 56 gastropod individuals of Muricidae were collected in Pulau Kapas. The species were *D. rugosa*, *M. spinosa* and *A. marginalba* (Figure 4.14). *Drupella rugosa* was the most common species found with 38 individuals, followed by *A. marginalba* (14 individuals) and *M. spinosa* (four individuals). *Drupella rugosa* recorded the highest and lowest number of individuals in ST and TJ with 34 and one, respectively. The greatest number of gastropods at Pulau Kapas was located in ST with 44 and fewer in KT and TJ with five and seven individuals, respectively. Although only a few gastropod individuals were found, TJ still recorded the highest number of species compared to KT and ST. None of the gastropods were documented in SR.

For *Frequency of Incidence, D. rugosa* and *A. marginalba* had the highest *FoI* with 75% as they were found at nearly all study sites in Pulau Kapas except SR. *Morula spinosa* contributed the least percentage of *FoI* (25%) as it was only found in TJ.

Table 4.5Abundance of coral reef gastropods in Pulau Kapas according to subclass, family and species between study sites. The total number of individuals and *Frequency of Incidence* are shown (TJ=Teluk Jawa, KT=Kapas Tengah, ST=Southern Tip and SR=Silent Reef). n=total no of individuals, *FoI*=*Frequency of Incidence* and - =none of gastropod present.

Subclass	**Family**	**Species**	**Study sites**				**Total of individuals (n)**	***FoI*(%)**
			TJ	**KT**	**ST**	**SR**		
Caenogastropoda	Muricidae	*Drupella rugosa*	1	3	34	-	38	75
		Morula spinosa	4	-	-	-	4	25
		Arakawania marginalba	2	2	10	-	14	75
Total of individuals			7	5	44	-	56	
Total species			3	2	2	-	3	

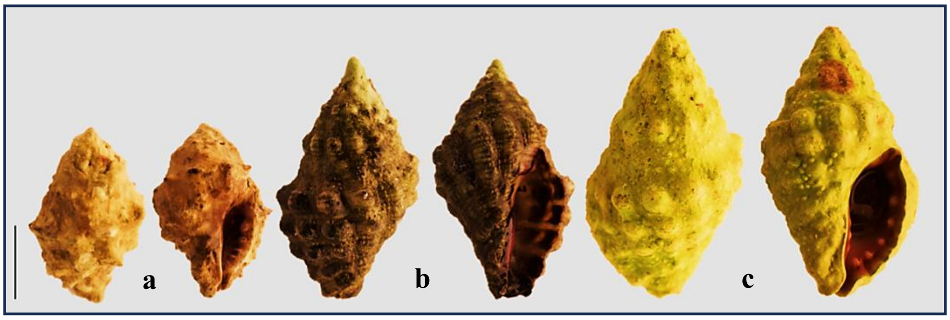

Figure 4.14 Coral reef gastropods of Muricidae in Pulau Kapas. a) *Morula spinosa*; b) *Arakawania marginalba*; c) *Drupella rugosa*. All specimens were photographed in apertural (left) and abapertural (right) views. Scale bar: 10 mm.

Based on the diversity indices values in Table 4.6, the highest Shannon diversity value was obtained from TJ with *H'*=0.956 while the lowest value was at ST (*H'*=0.536) for Pulau Kapas. Furthermore, the same pattern was also recorded for Simpson Index (*D*) with TJ having the largest value, *D*=0.571, compared to ST with only 0.350. Menhinick Index (*Me*) and Margalef Index (*Ma*) were the abundances of species per unit area in each site. Comparing both richness indices, TJ indicated greater values (*Me*=1.134 and *Ma*=1.028) than the other sites. In contrast, the values obtained for the Evenness and Equitability indices were higher in KT (J'=0.980) and (Ep=0.971).

Table 4.6 The diversity assessment of coral reef gastropods in Pulau Kapas (TJ=Teluk Jawa, KT=Kapas Tengah and ST=Southern Tip) and (*H'*=Shannon's diversity index, *D*=Simpson's diversity index, *Me*=Menhinick index, *Ma*=Margalef index, J'=Evenness index and Ep=Equitability index).

Study sites	***H'***	***D***	***Me***	***Ma***	**J'**	**Ep**
TJ	0.956	0.571	1.134	1.028	0.867	0.870
KT	0.673	0.480	0.894	0.621	0.980	0.971
ST	0.536	0.350	0.302	0.264	0.855	0.773

4.3.6 Pulau Yu Besar

The result indicated that 26 individuals of four species were discovered in Pulau Yu Besar. The species found were *D. cornus*, *D. rugosa, A. ceylonica* and *A. marginalba* (Figure 4.21). *Drupella rugosa* had the largest number, with 18 individuals recorded. The total number of individuals for *A. marginalba* and *D. cornus* were five and two, respectively.

The gastropods were predominantly found in S1, followed by S2 with no gastropods in S3. S1 and S2 recorded 18 and eight individuals of coral reef gastropods as *D. rugosa* contributed the most frequent species (14 individuals) and (four individuals) for both sites. Meanwhile, *A. ceylonica* had only one individual observed in S1. In addition, *D. cornus*, *D. rugosa* and *A. marginalba* scored the highest value of *FoI* with 67% (Table 4.13). The three species were discovered at two out of three sites, while *A. ceylonica* was only found in S1 with 33% of *FoI*.

Table 4.13 Abundance of coral reef gastropods in Pulau Yu Besar according to subclass, family and species between study sites. The total number of individuals and *Frequency of Incidence* are shown (S1=Site 1, S2=Site 2 and S3=Site 3). n=total no of individuals, *FoI=Frequency of Incidence* and - =none of gastropod present.

Subclass	**Family**	**Species**	**Study sites**			**Total of individuals (n)**	***FoI* (%)**
			S1	**S2**	**S3**		
Caenogastropoda	Muricidae	*Drupella cornus*	1	1	-	2	67
		Drupella rugosa	14	4	-	18	67
		Arakawania ceylonica	1	-	-	1	33
		Arakawania marginalba	2	3	-	5	67
Total of individuals			18	8	-	26	
Total species			4	3	-	4	

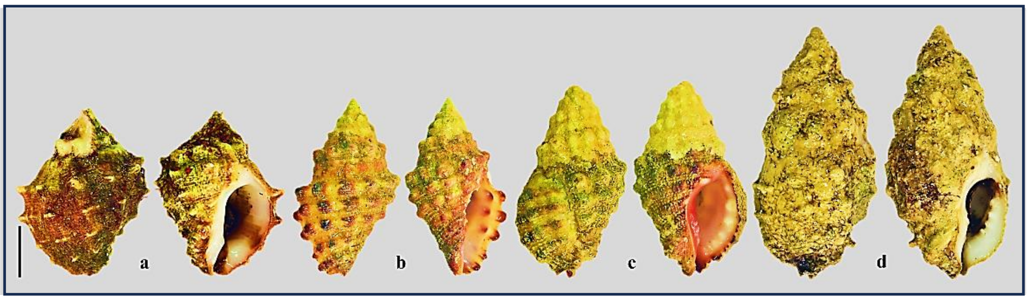

Figure 4.21 Coral reef gastropods of Muricidae in Pulau Yu Besar. a) *Drupella cornus*; b) *Arakawania marginalba*; c) *Drupella rugosa*; d) *Arakawania ceylonica*. All specimens were photographed in apertural (left) and abapertural (right) views. Scale bar: 10 mm.

Table 4.14 showed that the highest Shannon and Simpson diversity values were recorded in S2 (*H'*=0.974) and (*D*=0.594), while S1 contributed with (*H'*=0.761) and (*D*=0.377). The species richness of gastropods showed variation scores in S2 (*Me*=1.061, *Ma*=0.962) and S1 (*Me*=0.943, *Ma*=1.038) (Table 4.14). In addition, the results showed that the Evenness and Equitability indices were greater in S2, with J'=0.883 and Ep=0.887. In contrast, S1 recorded lower values with J'=0.535 and Ep=0.549.

Table 4.14 The diversity assessment of gastropods in Pulau Yu Besar (S1=Site 1 and S2=Site 2) and (*H'*=Shannon's diversity index, *D*=Simpson's diversity index, *Me*=Menhinick index, *Ma*=Margalef index, J'=Evenness index and Ep=Equitability index).

Study sites	***H'***	***D***	***Me***	***Ma***	**J'**	**Ep**
S1	0.761	0.377	0.943	1.038	0.535	0.549
S2	0.974	0.594	1.061	0.962	0.883	0.887

4.3.3 Pulau Perhentian

Five species of gastropods from Muricidae and Cerithiidae were found at 11 sites in Pulau Perhentian (Table 4.7). The coral reef gastropod species in Pulau Perhentian were *D. cornus, D. rugosa, M. spinosa* and *A. marginalba* (Figure 4.15). The other species included *C. columna* also found on the island (Figure 4.16). Apart from that, *D. rugosa* recorded the highest abundance with 140 individuals, followed by *A. marginalba* (42), *M. spinosa* (23) and *D. cornus* (four), respectively. *Cerithium columna* was found with one individual only compared to the other four species. No gastropods were found and recorded in TGG and CBY.

PR1 and PSB had higher species richness with four, while TPH had the lowest number with a single species. Although only three species were found at each site, PR2, SHP and TBS had the highest number of gastropod individuals with 77, 35 and 23, respectively. The other locations such as TPH, TTG, DLG, SBL and PSB, had almost similar patterns as the number of species was not less than ten individuals. PRN and BNS contributed the lowest number with only seven and six individuals at both sites.

The *FoI* of *D. rugosa* and *A. marginalba* were higher at 85% and 77% than those of the other species. The results indicated that *D. rugosa* and *A. marginalba* were almost distributed at all sites except TGG, TPH and CBY. *Morula spinosa* had 62% *FoI* as this species was still present at eight sites out of 13. *Cerithium columna* had the lowest (*FoI*=8%) because the species could be found only in PR1.

Table 4.7 Abundance of coral reef gastropods in Pulau Perhentian according to subclass, family and species between study sites. The total number of individuals and *Frequency of Incidence* are shown (TGG=Tanjung Genting, TPH= Teluk Pauh, PRN=Pulau Rawa North, PR1=Pulau Rawa South 1, TTG=Terumbu Tiga, SHP=Shark Point, TBS=Tanjung Basi, DLG=D'Lagoon, SBL=Seabell, BNS=Batu Nisam, CBY=Coral Bay, PR2=Pulau Rawa South 2 and PSB=Pinang Seribu). n=total no of individuals, *FoI=Frequency of Incidence* and - =none of gastropods present.

Subclass	Family	Species	Study sites													Total of individuals (n)	*FoI* (%)
			TGG	TPH	PRN	PR1	TTG	SHP	TBS	DLG	SBL	BNS	CBY	PR2	PSB		
Caenogastropoda	Cerithiidae	*Cerithium columna*	-	-	-	1	-	-	-	-	-	-	-	-	-	1	8
	Muricidae	*Drupella cornus*	-	-	2	1	-	-	-	-	-	-	-	-	1	4	23
		Drupella rugosa	-	10	3	13	7	18	13	7	5	3	-	52	9	140	85
		Morula spinosa	-	-	1	-	-	6	6	2	1	2	-	3	2	23	62
		Arakawania marginalba	-	-	1	4	5	3	4	7	9	1	-	6	2	42	77
Total of individuals			-	10	7	19	12	27	23	16	15	6	-	61	14	210	
Total of species			-	1	2	4	2	3	3	3	3	3	-	3	4	5	

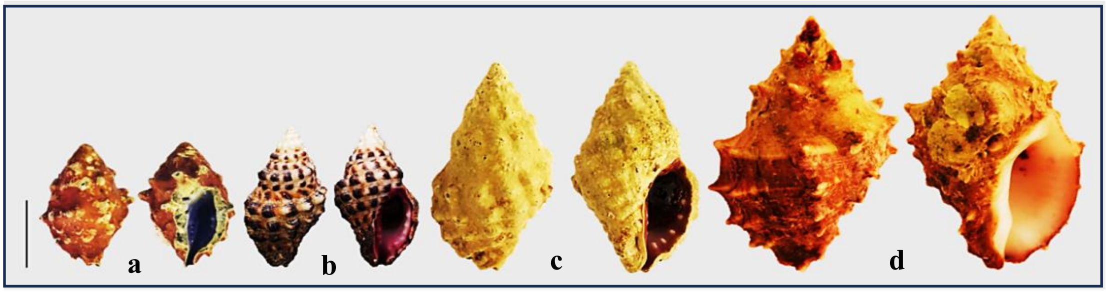

Figure 4.15 Coral reef gastropods of Muricidae in Pulau Perhentian. a) *Morula spinosa*; b) *Arakawania marginalba*; c) *Drupella rugosa*; d) *Drupella cornus*. All specimens were photographed in apertural (left) and abapertural (right) views. Scale bar: 10 mm.

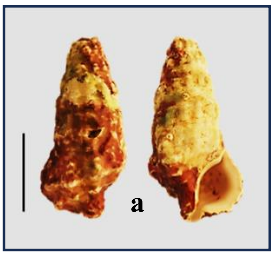

Figure 4.16 Coral reef gastropod of Cerithiidae in Pulau Perhentian; a) *Cerithium columna*. The specimen was photographed in apertural (left) and abapertural (right) views. Scale bar: 10 mm.

Table 4.8 showed the diversity values obtained at Pulau Perhentian. The site with the highest Shannon and Simpson Index values was found in PRN (*H'*=1.277 and *D*=0.694). TPH obtained a zero value for both indices as only one species could be found in the area. PRN gave high values for Margalef and Menhinick indices with (*Me*=1.512) and (*Ma*=1.542), reflecting a higher number of species recorded compared to the other sites in Pulau Perhentian (Table 4.8). TPH had the highest contribution with a value of Ep=1, while no value of J' was recorded in TPH. Considering that Evenness (J') and Equitability (Ep) indices have similar patterns for other sites with values lower than 1.

Table 4.8 The diversity assessment of coral reef gastropods in Pulau Perhentian (TPH=Teluk Pauh, PRN=Pulau Rawa North, PR1=Pulau Rawa South 1, TTG=Terumbu Tiga, SHP=Shark Point, TBS=Tanjung Basi, DLG=D' Lagoon, SBL=Seabell, BNS=Batu Nisam, PR2=Pulau Rawa South 2 and PSB=Pinang Seribu) and (*H'*=Shannon's diversity index, *D*=Simpson's diversity index, *Me*=Menhinick index, *Ma*=Margalef index, J'=Evenness index and Ep=Equitability index).

Study sites	***H'***	***D***	***Me***	***Ma***	**J'**	**Ep**
TPH	0	0	0	0	-	1
PRN	1.277	0.694	1.512	1.542	0.921	0.897
PR1	0.898	0.482	0.918	1.019	0.648	0.613
TTG	0.679	0.486	0.577	0.402	0.980	0.986
SHP	0.849	0.494	0.570	0.607	0.779	0.773
TBS	0.977	0.582	0.626	0.638	0.890	0.886
DLG	0.983	0.602	0.750	0.721	0.895	0.891
SBL	0.853	0.524	0.775	0.739	0.777	0.782
BNS	1.011	0.611	1.225	1.116	0.921	0.917
PR2	0.435	0.213	0.342	0.460	0.396	0.515
PSB	1.029	0.541	1.069	1.137	0.742	0.699

4.3.4 Pulau Redang

The three species of gastropods from Muricidae (Figure 4.17) and one species from Turbinidae (Figure 4.18) were found in Pulau Redang. A total of 177 individuals were recorded in all sites. The number of gastropods was highest at TK with 94 individuals from three species, followed by KB (51 individuals and three species) (Table 4.9). PL had the fewest gastropods with 32 individuals. Although most species were still present in PL, it recorded the lowest number of individuals compared to KB and TK. No gastropods were found in CH and MC.

Among four gastropod species, *D. rugosa* was the most abundant with a total of 112 individuals recorded; 57 in TK, 41 in KB, and 14 in PL. *Arakawania marginalba* was the second most abundant with 43 individuals, which 31 were found in TK, nine in KB and three in PL. *Morula spinosa* recorded 12 individuals with six in TK, one in KB and five in PL. The *FoI* was 60% for *D. rugosa*, *M. spinosa* and *A. marginalba*. *Astralium rhodostomum* had the lowest number with ten individuals found in PL and only contributed 20% of *FoI*.

Table 4.9 Abundance of coral reef gastropods in Pulau Redang according to subclass, family and species between study sites. The total number of individuals and *Frequency of Incidence* are shown (KB=Kerengga Besar, PL=Pulau Lima, TK=Terumbu Kili, CH=Chagar Hutang and MC=Mak Cantik). n=total no of individuals, *FoI*=*Frequency of Incidence* and - =none of gastropod present.

Subclass	**Family**	**Species**	**Study sites**					**Total of individuals (n)**	***FoI* (%)**
			KB	**PL**	**TK**	**CH**	**MC**		
Vetigastropoda	Turbinidae	*Astralium rhodostomum*	-	10	-	-	-	10	20
		Drupella rugosa	41	14	57	-	-	112	60
Caenogastropoda	Muricidae	*Morula spinosa*	1	5	6	-	-	12	60
		Arakawania marginalba	9	3	31	-	-	43	60
Total of individuals			51	32	94	-	-	177	
Total species			3	4	3	-	-	4	

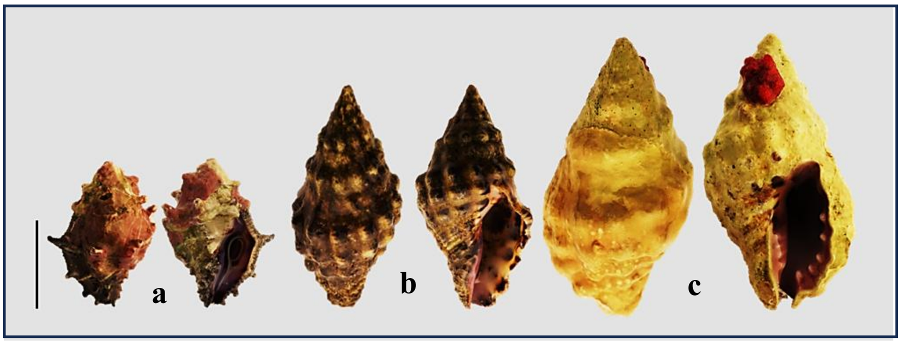

Figure 4.17 Coral reef gastropods from Muricidae in Pulau Redang. a) *Morula spinosa*; b) *Arakawania marginalba*; c) *Drupella rugosa*. All specimens were photographed in apertural (left) and abapertural (right) views. Scale bar: 10 mm.

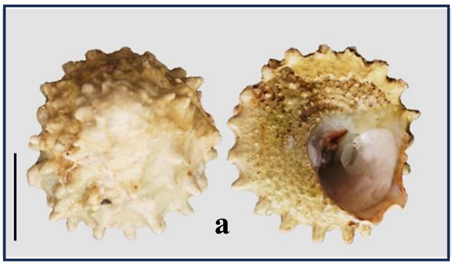

Figure 4.18 Coral reef gastropods of Turbinidae in Pulau Redang. a) *Astralium rhodostomum*. The specimen was photographed in apertural (left) and abapertural (right) views. Scale bar: 10 mm.

Table 4.10 showed diversity indices of gastropods from sites of Pulau Redang. PL scored higher values for both the Shannon index and Simpson index compared to KB and TK, with 1.237 and 0.680 (Table 4.10). In addition, the Menhinick and Margalef Index value of Pulau Lima also indicated higher than KB and TK values with *Me*=0.707 and *Ma*=0.866. Moreover, the Evenness and Equitability indices of PL followed the same trend as both values were higher than those of other sites in Pulau Redang, with J'=0.861 and Ep=0.892 (Table 4.10).

Table 4.10 The diversity assessment of coral reef gastropods in Pulau Redang (KB=Kerengga Besar, PL=Pulau Lima and TK=Terumbu Kili) and (*H'*=Shannon's diversity index, *D*=Simpson's diversity index, *Me*=Menhinick index, *Ma*=Margalef index, J'=Evenness index and Ep=Equitability index).

Study sites	***H'***	***D***	***Me***	***Ma***	**J'**	**Ep**
KB	0.724	0.372	0.509	0.687	0.413	0.450
PL	1.237	0.680	0.707	0.866	0.861	0.892
TK	0.845	0.520	0.309	0.440	0.776	0.769

4.3.5 Pulau Tenggol

A total of 53 individuals representing five species of Muricidae (Figure 4.19) and Cerithiidae (Figure 4.20) were recorded in Pulau Tenggol. Table 4.11 indicated that LW contributed the most abundant gastropods with 28 individuals. Meanwhile, TR and RJ had the fewest with only two. The number of recorded species varied in each sampling site with LW contributed the highest species richness (four), followed by SN and TP. Only one species of gastropod was recorded in both TR and RJ.

Drupella rugosa recorded more gastropods with 35 individuals. The other species such as *A. marginalba, C. violacea* and *D. cornus* were recorded with four, five and eight individuals, respectively. The least species, *C. coralium* was recorded with only one individual found in Pulau Tenggol. *FoI* for *D. rugosa* was the highest with 80%, followed by 40% for *C. violacea* and *D. cornus*. Lastly, *C. coralium* and *A. marginalba* showed the lowest value with only 20%.

Table 4.11 Abundance of coral reef gastropods in Pulau Tenggol according to subclass, family and species between study sites. The total number of individuals and *Frequency of Incidence* are shown (TP =Turtle Point, TR=Teluk Rajawali, RJ= Rajawali, SN= Sri Nakhota and LW=Lost World). n=total no of individuals, *FoI*=*Frequency of Incidence* and - =none of gastropod present.

Subclass	**Family**	**Species**	**Study sites**					**Total of individuals (n)**	***FoI* (%)**
			TP	**TR**	**RJ**	**SN**	**LW**		
Caenogastropoda	Muricidae	*Drupella rugosa*	2	-	2	16	15	35	80
		Arakawania marginalba	-	-	-	-	4	4	20
		Coralliophila violacea	-	2	-	-	3	5	40
		Drupella cornus	2	-	-	-	6	8	40
	Cerithiidae	*Cerithium coralium*	-	-	-	1	-	1	20
Total of individuals			4	2	2	17	28	53	
Total species			2	1	1	2	4	5	

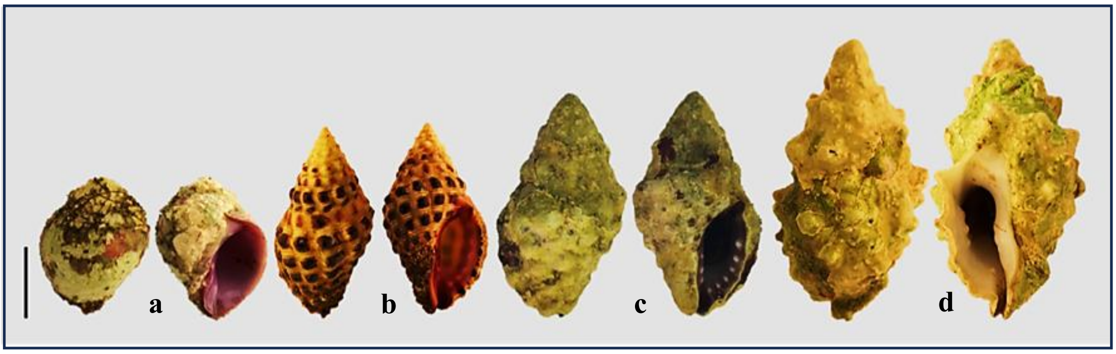

Figure 4.19 Coral reef gastropods of Muricidae in Pulau Tenggol. a) *Coralliophila violacea*; b) *Arakawania marginalba*; c) *Drupella rugosa*; d) *Drupella cornus*. All specimens were photographed in apertural (left) and abapertural views (right). Scale bar: 10 mm.

Figure 4.20 Coral reef gastropod of Cerithiidae in Pulau Tenggol. a) *Cerithium coralium*. The specimen was photographed in apertural and abapertural views. Scale bar: 10 mm.

Table 4.12 showed that the gastropods from LW had higher diversity as the Shannon and Simpson values (*H'*=1.182, *D*=0.635) were higher than other sites in Pulau Tenggol. TR and RJ displayed zero values for the Shannon and Simpson indices as only one species was present in both TP and LW (Table 4.12). The species richness values were generally higher in TP (*Me*=1 and *Ma*=0.721) and LW (*Me*=0.756 and *Ma*=0.900). However, for Margalef index values, both TR and RJ contributed zero, meaning that a low number of species was present in the community. The Evenness (J') and Equitability (Ep) values varied across the sites in Pulau Tenggol. An almost complete homogeneity of gastropod species was observed at TP, TR and RJ as the Evenness value (J') for each site reached one (Table 4.12).

Table 4.12 The diversity assessment of coral reef gastropods in Pulau Tenggol (TP=Turtle Point, TR=Teluk Rajawali, RJ=Rajawali, SN=Sri Nakhota and LW=Lost World) and (*H'*=Shannon's diversity index, *D*=Simpson's diversity index, *Me*=Menhinick index, *Ma*=Margalef index, J'=Evenness index and Ep=Equitability index).

Study sites	***H'***	***D***	***Me***	***Ma***	**J'**	**Ep**
TP	0.693	0.500	1	0.721	1	1
TR	0	0	0.707	0	1	-
RJ	0	0	0.707	0	1	-
SN	0.349	0.198	0.471	0.346	0.709	0.503
LW	1.182	0.635	0.756	0.900	0.815	0.853

4.3.7 Pulau Yu Kecil

Five species from Muricidae were found in Pulau Yu Kecil; *D. cornus, D. rugosa, M. spinosa, A. ceylonica* and *A. marginalba. Drupella rugosa* was the most abundant species with 39 individuals. Additionally, *M. spinosa* and *A. marginalba* were represented by 17 and 11 individuals, respectively. Meanwhile, only three individuals of *D. cornus* and one individual of *A. ceylonica* were recorded (Table 4.15). Among the sampling sites, S3 contributed the highest number of individuals (40), followed by S1 with 18 and S2 with 13.

Both *D. cornus* and *M. spinosa* contributed for 67% of *FoI* as these species were present at two out of the three sampling sites. The other species such as *D. rugosa, A. ceylonica* and *A. marginalba* represented only 33% of *FoI* as each was recorded at a single site in Pulau Yu Kecil (Table 4.15).

Table 4.15 Abundance of coral reef gastropods in Pulau Yu Kecil according to subclass, family and species between study sites. The total number of individuals and *Frequency of Incidence* (*FoI*) are also shown (S1=Site 1, S2=Site 2 and S3=Site 3). n=total no of individuals, *FoI=Frequency of Incidence* and - = none of gastropod present.

Subclass	**Family**	**Species**	**Sites**			**Total of individuals (n)**	**FoI (%)**
			S1	**S2**	**S3**		
Caenogastropoda	Muricidae	*Drupella cornus*	2	-	1	3	67
		Drupella rugosa	-	-	39	39	33
		Morula spinosa	15	2	-	17	67
		Arakawania ceylonica	1	-	-	1	33
		Arakawania marginalba	-	11	-	11	33
Total of individuals			18	13	40	71	
Total species			3	3	2	5	

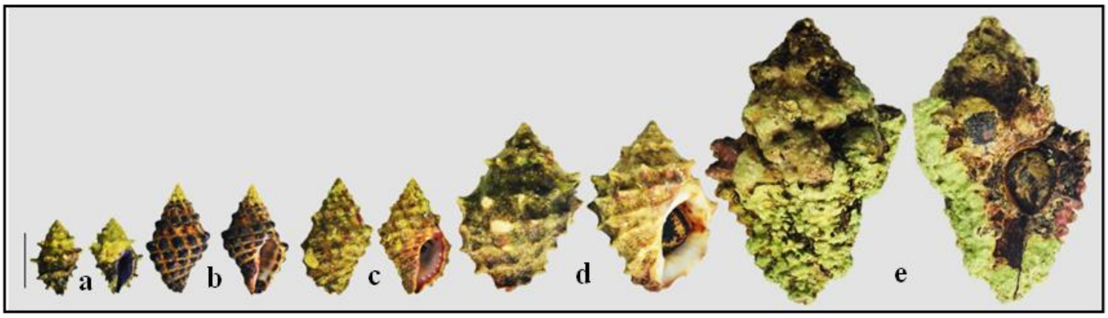

Figure 4.22 Coral reef gastropods from Muricidae in Pulau Yu Kecil. a) *Morula spinosa*; b) *Arakawania marginalba*; c) *Drupella rugosa*; d) *Drupella cornus*; e) *Arakawania ceylonica*. All specimens were photographed in apertural (left) and abapertural (right) views. Scale bar: 10 mm.

Table 4.16 presented the variation in gastropod diversity across Pulau Yu Kecil. The highest Shannon (*H'*) and Simpson (*D*) values were recorded at S1 (*H'*=0.557, *D*=0.290), while the lowest values were observed at S3 (*H'*=0.117, *D*=0.049). The Menhinck (*Me*) and Margalef (*Ma*) indices also varied among the sites, with S1 showing the highest values (*Me*=0.707, Ma=0.692) compared to the other sites (Table 4.16). Meanwhile, S3 still recorded the lowest values for both indices (*Me*=0.316, *Ma*=0.271). However, the highest values for Evenness (J') and Equitability (Ep) were recorded at S2 with J'=0.768 and Ep=0.619, respectively. In contrast, Site 3 contributed the lowest value for both indices with J'=0.562 and Ep=0.169 (Table 4.16).

Table 4.16 The diversity assessment of gastropods in Pulau Yu Kecil (S1=Site 1, S2=Site 2 and S3=Site 3) and (*H'*=Shannon's diversity index, *D*=Simpson's diversity index, *Me*=Menhinick index, *Ma*=Margalef index, J'=Evenness index and Ep=Equitability index).

Study sites	***H'***	***D***	***Me***	***Ma***	**J'**	**Ep**
S1	0.557	0.290	0.707	0.692	0.582	0.507
S2	0.429	0.260	0.555	0.399	0.768	0.619
S3	0.117	0.049	0.316	0.271	0.562	0.169

4.4 Shell metric and biomass among islands

Table 4.17 presented the variation in shell length (mm), dry weight (g) and condition index for each gastropod species recorded in the marine protected islands of Terengganu. The result indicated the significant differences ($p<0.05$) between shell lengths of the same species among islands at a 95% confidence interval. Post-hoc Tukey analysis revealed that *DRG* and *AMG* from PTG exhibited the longest shell length with 31.55 ± 3.27 mm and 29.87 ± 5.34 mm, respectively. In contrast, the shortest shell length for *DRG* and *AMG* were found at PPH and PRD with 25.40 ± 2.23 mm and 16.77 ± 6.34 mm. *MRS* from PYK and PKS exhibited the highest value of shell length with 25.17 ± 2.96 mm and 20.54 ± 2.23 mm. Meanwhile, the shortest shell of *MRS* was found in PRD with only 15.15 ± 4.14 mm. *Drupella cornus* (*DCR*) from PBD recorded the largest value of shell length with 40.72 ± 2.33 mm, whereas the smallest value of shell length was recorded at PPH with 20.55 ± 10.23 mm. *Arakawania ceylonica* (*ACY*) from PYK showed the greatest shell length with 74.39 mm compared to *ACY* from PYB (43.41 mm). However, the other gastropods recorded in Terengganu marine protected islands exhibited the following shell length: *ARD* (9.23 ± 6.14 mm), *CVL* (22.80 ± 6.18 mm), *CCR* (44.70 mm) and *CCL* (21.29 mm).

A similar trend was also observed in dry weight where one-way ANOVA revealed a significant difference ($p<0.05$) among gastropod species at a 95% confidence interval. Nevertheless, the dry weights of *DRG* and *AMG* from PTG were higher than those from other islands with values of 4.97 ± 1.76 g and 2.19 ± 0.49 g. In contrast, the lightest dry weight for *DRG* and *AMG* were found in PPH and PRD with 2.74 ± 0.71 g and 1.08 ± 1.05 g, respectively. For *MRS*, the individuals from PYK contributed the heaviest dry weight (2.74 ± 0.91 g), while the lightest was recorded in PRD with 0.93 ± 0.56 g. In comparing the dry weight of *DCR* across the islands, the highest value was observed in PBD (13.84 ± 4.23 g), whereas PPH indicated the lowest with 2.65 ± 2.49 g. The individual of *ACY* from PYK contributed the highest dry weight value with 61.85 g compared to the individual recorded in PYB. The dry weights for other gastropod species such as *ARD*, *CVL*, *CCR* and *CCL* were 9.23 ± 6.14 g, 4.79 ± 3.06 g, 10.28 g and 1.29 g.

There were no significant differences ($p>0.05$) for the condition index of almost all species at a 95% confidence interval. The condition index (*CI*) for *DRG, MRS* and *DCR* showed relatively similar patterns across the islands. However, a significant difference ($p<0.05$) was observed for *AMG* as the individuals from PPH recorded the highest *CI* value with 1.14 ± 0.16 and the lowest was found in PTG (0.96 ± 0.25). In addition, *ACY* individuals from PYB and PYK showed similar values with 1.07. The condition index for *ARD*, *CVL*, *CCR* and *CCL* were 1.10 ± 0.06, 1.73 ± 1.44, 1.04 and 1.09, respectively.

Table 4.17 Shell length (mm), dry weight (g) and condition index of coral reef gastropods in Terengganu marine protected islands. PPH=Pulau Perhentian, PRD=Pulau Redang, PKS=Pulau Kapas, PTG=Pulau Tenggol, PYB=Pulau Yu Besar, PYK=Pulau Yu Kecil, PBD=Pulau Bidong; *DRG=Drupella rugosa*, *AMG=Arakawania marginalba*, *MRS=Morula spinosa*, *DCR=Drupella cornus*, *ARD=Astralium rhodostomum*, *CVL=Coralliophila violacea*, *ACY=Arakawania ceylonica*, *CCR=Cerithium coralium* and *CCL=Cerithium columna*, (n)=total number of individuals and - =none of the gastropods present.

Metrics	Species	Study sites							p-value sites
		PPH	**PRD**	**PKS**	**PTG**	**PYB**	**PYK**	**PBD**	
Shell length (mm)	*DRG*	25.40 ± 2.23 (140)	28.00 ± 2.25 (81)	25.93 ± 1.93 (38)	31.55 ± 3.27 (35)	29.40 ± 2.06 (18)	28.06 ± 2.23 (39)	26.55 ± 2.46 (97)	F=38.63, p=9.19E-38 (<0.05) PPH<PKS<PBD<PRD<PYK<PYB<PTG
	AMG	20.70 ± 4.88 (42)	16.77 ± 6.34 (43)	23.79 ± 5.97 (14)	29.87 ± 5.34 (4)	21.66 ± 8.93 (5)	26.79 ± 1.90 (11)	17.28 ± 1.10 (2)	F=5.83, p=2.46E-05 (<0.05) PRD<PBD<PPH<PYB<PKS<PYK<PTG
	MRS	17.09 ± 3.30 (23)	15.15 ± 4.14 (12)	20.54 ± 2.23 (4)	-	-	25.17 ± 2.96 (17)	16.94 ± 3.74 (6)	F=13.74, p=5.20E-08 (<0.05) PRD<PBD<PPH<PKS<PYK
	DCR	20.55 ± 10.23 (4)	-	-	31.46 ± 2.75 (8)	33.80 ± 14.86 (2)	33.55 ± 7.71 (3)	40.72 ± 2.33 (6)	F=4.22, p=0.015 (<0.05) PPH<PTG<PYB<PYK<PBD
	ARD	-	9.23 ± 6.14 (10)	-	-	-	-	-	NE
	CVL	-	-	-	22.80 ± 6.18 (5)	-	-	-	NE
	ACY	-	-	-	-	43.41 (1)	74.39 (1)	-	NE
	CCR	-	-	-	44.70 (1)	-	-	-	NE
	CCL	21.29 (1)	-	-	-	-	-	-	NE
Dry weight (g)	*DRG*	2.74 ± 0.71 (140)	3.71 ± 0.73 (81)	2.78 ± 0.60 (38)	4.97 ± 1.76 (35)	3.72 ± 0.73 (18)	3.46 ± 0.66 (39)	3.19 ± 0.75 (97)	F=35.43, p=5.08E-35 (<0.05) PPH<PKS<PBD<PYK<PRD<PYB<PTG
	AMG	1.34 ± 0.86 (42)	1.08 ± 1.05 (43)	1.71 ± 0.91 (14)	2.19 ± 0.49 (4)	1.38 ± 1.47 (5)	1.95 ± 0.46 (11)	1.09 ± 0.01 (2)	F=2.81, p=0.014 (<0.05) PRD<PBD<PPH<PYB<PKS<PYK<PTG
	MRS	1.16 ± 0.63 (23)	0.93 ± 0.56 (12)	1.97 ± 0.74 (4)	-	-	2.74 ± 0.91 (17)	1.10 ± 0.70 (8)	F=7.79, p=3.98E-05 (<0.05) PRD<PBD<PPH<PKS<PYK
	DCR	2.65 ± 2.49 (4)	-	-	4.42 ± 1.28 (8)	10.11 ± 9.73 (2)	9.68 ± 5.88 (3)	13.84 ± 4.23 (6)	F=3.87, p=0.021 (<0.05) PPH<PTG<PYK<PYB<PBD

Cont

	ARD	-	9.23 ± 6.14 (10)	-	-	-	-	-	NE
	CVL	-	-	-	4.79 ± 3.06 (5)	-	-	-	NE
	ACY	-	-	-	-	12.93 (1)	61.85 (1)	-	NE
	CCR	-	-	-	10.28 (1)	-	-	-	NE
	CCL	1.29 (1)	-	-	-	-	-	-	NE
Condition index	*DRG*	1.09 ± 0.08 (140)	1.12 ± 0.19 (81)	1.09 ± 0.19 (38)	1.06 ± 0.06 (35)	1.15 ± 0.21 (18)	1.07 ± 0.09 (39)	1.12 ± 0.48 (97)	F=1.079, p=0.374 (>0.05) PTG;PYK;PPH;PKS;PRD;PBD;PYB
	AMG	1.14 ± 0.16 (42)	1.11 ± 0.06 (43)	1.01 ± 0.04 (14)	0.96 ± 0.25 (4)	1.11 ± 0.06 (5)	1.08 ± 0.01 (11)	1.09 ± 0.01 (2)	F=4.667, p=2.8E-04 (<0.05) PTG<PKS<PYK<PBD<PRD;PYB<PPH
	MRS	1.11 ± 0.17 (23)	1.07 ± 0.03 (12)	1.06 ± 0.01 (4)	-	-	1.05 ± 0.06 (17)	0.93 ± 0.36 (8)	F=1.978, p=1.096 (>0.05) PBD<PYK<PKS<PRD<PPH
	DCR	1.07 ± 0.04 (4)	-	-	1.06 ± 0.01 (8)	1.08 ± 0.04 (2)	1.13 ± 0.04 (3)	1.08 ± 0.03 (6)	F=2.68, p=0.065 (>0.05) PTG;PPH;PYB;PBD;PYK
	ARD	-	1.10 ± 0.06 (10)	-	-	-	-	-	NE
	CVL	-	-	-	1.73 ± 1.44 (5)	-	-	-	NE
	ACY	-	-	-	-	1.07 (1)	1.07 (1)	-	NE
	CCR	-	-	-	1.04 (1)	-	-	-	NE
	CCL	1.09 (1)	-	-	-	-	-	-	NE

4.5 Shell metric and biomass within islands

Table 4.18 showed the shell length (mm), dry weight (g) and condition index of gastropods recorded in Pulau Bidong. The result indicated the significant differences ($p<0.05$) for shell length and dry weight, while the condition index showed no significant difference ($p>0.05$). Post-hoc Tukey analysis revealed that *DRG* from PPK exhibited the longest shell length (27.89 ± 20.50 mm) compared to individuals in PPC. *Drupella rugosa* from PPK also displayed higher dry weight and condition index values with 3.58 ± 0.60 g and 1.18 ± 0.76 compared to those from PPC (2.93 ± 0.75 g, 1.08 ± 0.02).

The significant differences for *DCR, MRS,* and *AMG* were not evaluated (NE) as each species was only found in one study site across the islands. The shell length, dry weight and condition index of *DCR* were 38.46 ± 5.80 mm, 11.36 ± 5.67 g and 1.08 ± 0.03. Additionally, the shell lengths of *MRS* and *AMG* were 15.15 ± 1.73 mm and 22.31 ± 2.49 mm. The dry weight and condition index of *MRS* were 0.77 ± 0.23 g and 0.89 ± 0.42, while individuals of *AMG* recorded values of 2.11 ± 0.64 g and 1.03 ± 0.03, respectively (Table 4.18).

Table 4.18 Shell length (mm), dry weight (g) and condition index of coral reef gastropods in Pulau Bidong (DLT=Dinding Laut, PPK=Pantai Pasir Pengkalan and PPC=Pantai Pasir Cina). *DRG*=*Drupella rugosa*, *DCR*=*Drupella cornus*, *MRS*=*Morula spinosa* and *AMG*=*Arakawania marginalba*, (n)=total number of individuals and - =none of the gastropods present also shown.

Metrics	**Species**	**Study sites**			**p-value sites**
		DLT	**PPK**	**PPC**	
Shell length (mm)	*DRG*	-	27.89 ± 20.50 (40)	25.6 ± 2.35 (57)	F=24.66, p=3.46E-06 (<0.05) PPC<PPK
	DCR	38.46 ± 5.80 (6)	-	-	NE
	MRS	-	-	15.15 ± 1.73 (6)	NE
	AMG	-	-	22.31 ± 2.49 (2)	NE
Dry weight (g)	*DRG*	-	3.58 ± 0.60 (40)	2.93 ± 0.75 (57)	F=22.83, p=8.32E-06 (<0.05) PPC<PPK
	DCR	11.36 ± 5.67 (6)	-	-	NE
	MRS	-	-	0.77 ± 0.23 (6)	NE
	AMG	-	-	2.11 ± 0.64 (2)	NE
Condition index	*DRG*	-	1.18 ± 0.76 (40)	1.08 ± 0.02 (57)	F=0.13, p=0.721 (> 0.05) PPK; PPC
	DCR	1.08 ± 0.03 (6)	-	-	NE
	MRS	-	-	0.89 ± 0.42 (6)	NE
	AMG	-	-	1.03 ± 0.03 (2)	NE

The result in Table 4.19 showed the values of shell length, dry weight, and condition index for *DRG, MRS,* and *AMG* in Pulau Kapas. For *DRG* and *MRS*, the shell metric and biomass were not evaluated (NE). However, one-way ANOVA revealed there were significant differences in shell length and dry weight ($p<0.05$) for *AMG*, while no significant difference was observed in its condition index ($p>0.05$).

For *DRG,* the longest shell was observed at TJ with 28.19 mm, followed by individuals in KT (26.52 ± 0.78 mm) and ST (25.81 ± 1.99 mm), respectively. A similar trend was also shown in dry weight with *DRG* in TJ obtaining the highest value (3.13 g), followed by individuals in KT (2.82 ± 0.28 g) and ST (2.76 ± 0.63 g). Meanwhile, the shell length, dry weight and condition of *MRS* were 20.54 ± 2.23 mm, 1.97 ± 0.74 g and 1.06 ± 0.01, respectively (Table 4.19).

Among *AMG*, Post hoc Tukey revealed that the individuals from TJ contributed the highest value for shell length with 27.74 ± 1.12 mm. The shell lengths recorded in ST and KT were 25.29 ± 3.85 mm and 25.29 ± 3.85 mm. The dry weight of *AMG* showed that individuals from TJ displayed the largest value (3.13 g), followed by ST (1.82 ± 0.74 g) and KT (0.28 ± 0.23 g), respectively (Table 4.19). The condition index did not differ significantly as the values of *CI* showed similar patterns across all study sites.

Table 4.19 Shell length (mm), dry weight (g) and condition index of coral reef gastropods in Pulau Kapas (TJ=Teluk Jawa, KT=Kapas Tengah and ST=Southern Tip). *DRG=Drupella rugosa*, *MRS=Morula spinosa* and *AMG=Arakawania marginalba*; (n)=total number of individuals and - =none of the gastropods present are also shown.

Metrics	**Species**	**Study sites**			**p-value sites**
		TJ	**KT**	**ST**	
Shell length (mm)	*DRG*	28.19 (1)	26.52 ± 0.78 (3)	25.81 ± 1.99 (34)	NE
	MRS	20.54 ± 2.23 (4)	-	-	NE
	AMG	27.74 ± 1.12 (2)	12.37 ± 3.78 (2)	25.29 ± 3.85 (10)	F=16.84, p=0.0003 (<0.05) KT<ST<TJ
Dry weight (g)	*DRG*	3.13 (1)	2.82 ± 0.28 (3)	2.76 ± 0.63 (34)	NE
	MRS	1.97 ± 0.74 (4)	-	-	NE
	AMG	2.56 ± 0.12 (2)	0.28 ± 0.23 (2)	1.82 ± 0.74 (10)	F=13.03, p=0.001 (<0.05) KT<ST<TJ
Condition index	*DRG*	1.11 (1)	1.11 ± 0 (3)	1.1 ± 0.2 (34)	NE
	MRS	1.06 ± 0.01 (4)	-	-	NE
	AMG	0.96 ± 0.13 (2)	1.09 ± 0.06 (2)	1.00 + 0.27 (10)	F=0.11, p=0.898 (>0.05) TJ; ST; KT

The shell metrics and biomass of *CCL, DCR, DRG, MRS* and *AMG* in Pulau Perhentian were recorded in Table 4.20. The results indicated both significant ($p<0.05$) and no significant ($p>0.05$) differences in shell length, dry weight and condition index for *DRG* across the study sites. One-way ANOVA showed significant differences in *DRG'*s shell length and dry weight ($p<0.05$). Post hoc Tukey revealed that the individuals from DLG exhibited the greatest shell length with 28.29 ± 0.75 mm, followed by species in TPH (27.23 ± 1.51 mm), respectively (Table 4.20). The shortest shell lengths were recorded at PR1 (22.65 ± 1.88 mm) and TTG (22.55 ± 1.00 mm). A similar trend was observed in dry weight, where *DRG* in SBL exhibited the highest value (3.42 ± 0.51 g), followed by DLG (3.29 ± 0.37 g) (Table 4.20). The individuals from PR1 (1.86 ± 0.29 g) and TTG (22.55 ± 1.00 g) showed the lowest dry weights. However, no significant difference was observed in the condition index for *DRG* ($p>0.05$) as the values were relatively similar across sites (Table 4.20).

The shell length, dry weight and condition index for *DCR*, *MRS* and *AMG* were not evaluated (NE) in Pulau Perhentian (Table 4.20). Although these species were not evaluated as only a single individual of each species was observed at the study sites, their shell lengths were still notable; 19.44 mm for *DCR* in PR1, 21.67 ± 1.66 mm for *MRS* in PSB and 23.79 ± 2.83 mm for *AMG* in PR1 (Table 4.20). The shortest shell lengths for *DCR, MRS* and *AMG* were recorded at 13.85 ± 3.51 mm in PRN, 13.52 mm in PRN and 10.46 mm in BNS, respectively. A similar pattern was observed for the highest dry weights; *DCR* in PR1 (1.81g), *MRS* in SBL (2.10 g) and *AMG* in PR1 (2.22 ± 0.96 g). In contrast, the lowest dry weights for *DCR, MRS* and *AMG* were 1.22 ± 0.30 g, 0.85 ± 0.58 g and 0.27 g. The highest condition index (*CI*) values were recorded in PR1 for *DCR* (1.12), SBL for *MRS* (1.87) and PR2 for *AMG* (1.32) (Table 4.20). Meanwhile, the lowest *CI* values for *DCR, MRS* and *AMG* were 1.06 ± 0.02, 1.04 ± 0.03 and 1.02. *CCL* was not evaluated (NE) as only a single individual was observed. The shell length, dry weight and condition index for this species were 21.29 mm, 1.29 g and 1.09, respectively.

Table 4.20 Shell length (mm), dry weight (g) and condition index of coral reef gastropods in Pulau Perhentian (TPH= Teluk Pauh, PRN=Pulau Rawa North, PR1=Pulau Rawa South 1, TTG=Terumbu Tiga, SHP=Shark Point, TBS=Tanjung Basi, DLG=D'Lagoon, SBL=Seabell, BNS=Batu Nisam, PR2=Pulau Rawa South 2 and PSB=Pinang Seribu). *CCL=Cerithium columna, DCR=Drupella cornus, DRG=Drupella rugosa, MRS=Morula spinosa* and *AMG=Arakawania marginalba,* (n)=total number of individuals and - =none of the gastropods present are also shown.

Metrics	Species	Study sites											p-value sites
		TPH	PRN	PR1	TTG	SHP	TBS	DLG	SBL	BNS	PR2	PSB	
Shell length (mm)	*CCL*	-	-	21.29 (1)	-	-	-	-	-	-	-	-	NE
	DCR	-	13.85 ± 3.51 (2)	19.44 (1)	-	-	-	-	-	-	-	35.07 (1)	NE
	DRG	27.23 ± 1.51 (10)	25.72 ± 0.64 (3)	22.65 ± 1.88 (13)	22.55 ± 1.00 (7)	26.04 ± 1.03 (18)	25.49 ± 1.99 (13)	28.29 ± 0.75 (7)	27.09 ± 1.81 (5)	27.0 ± 1.62 (3)	25.12 ± 1.86 (52)	25.89 ± 2.15 (9)	F=8.95, p=4.27E-11 (<0.05) TTG<PR1<PR2<TBS<PRN< PSB<SHP<SBL<BNS<TPH <DLG
	MRS	-	13.52 (1)	-	-	16.81 ± 0.71 (6)	16.33 ± 2.99 (6)	18.22 ± 6.33 (2)	20.75 (1)	16.18 ± 6.39 (2)	15.96 ± 3.79 (3)	21.67 ± 1.66 (2)	NE
	AMG	-	21.85 (1)	23.79 ± 2.83 (4)	21.84 ± 5.29 (5)	22.22 ± 4.68 (3)	20.77 ± 6.16 (4)	22.29 ± 2.54 (7)	20.88 ± 2.16 (9)	10.46 (1)	18.06 ± 8.09 (6)	15.38 ± 2.21 (2)	NE
Dry weight (g)	*CCL*	-	-	1.29 (1)	-	-	-	-	-	-	-	-	NE
	DCR	-	1.22 ± 0.30 (2)	1.81 (1)	-	-	-	-	-	-	-	6.36 (1)	NE
	DRG	3.09 ± 0.42 (10)	2.76 ± 0.44 (3)	1.86 ± 0.29 (13)	1.93 ± 0.23 (7)	3.12 ± 0.97 (18)	2.55 ± 0.38 (13)	3.29 ± 0.37 (7)	3.42 ± 0.51 (5)	2.59 ± 0.29 (3)	2.72 ± 0.64 (52)	3.06 ± 0.43 (9)	F=8.209, p=3.26E-10 (<0.05) TTG<PR1<PR2<TBS<PRN< PSB<SHP<SBL<BNS<TPH <DLG

Cont

	MRS	-	1.31 (1)	-	-	1.05 ± 0.25 (6)	0.85 ± 0.58 (6)	1.31 ± 1.00 (2)	2.10 (1)	1.18 ± 0.78 (2)	1.18 ± 0.40 (3)	1.99 ± 0.89 (2)	NE
	AMG	-	1.90 (1)	2.22 ± 0.96 (4)	1.70 ± 0.92 (5)	1.61 ± 0.83 (3)	1.97 ± 0.28 (4)	1.57 ± 0.53 (7)	1.28 ± 0.49 (9)	0.27 (1)	1.26 ± 1.10 (6)	0.44 ± 0.18 (2)	NE
Condition index	*CCL*	-	-	1.09 (1)	-	-	-	-	-	-	-	-	NE
	DCR	-	1.06 ± 0.02 (2)	1.12 (1)	-	-	-	-	-	-	-	1.03 (1)	NE
	DRG	1.08 ± 0.02 (10)	1.10 ± 0.05 (3)	1.10 ± 0.15 (13)	1.10 ± 0.07 (7)	1.09 ± 0.04 (18)	1.11 ± 0.12 (13)	1.07 ± 0.02 (7)	1.08 ± 0.01 (3)	1.12 ± 0.06 (3)	1.10 ± 0.05 (52)	1.01 ± 0.18 (9)	F=1.526. p=0.137 (>0.05) TPH; PRN; PR1; TTG; SHP; TBS; DLG; SBL; BNS; PR2; PSB
	MRS	-	1.08 (1)	-	-	1.07 ± 0.02 (6)	1.09 ± 0.04 (6)	1.12 ± 0.01 (2)	1.87 (1)	1.06 ± 0.01 (2)	1.04 ± 0.03 (3)	1.07 ± 0.02 (2)	NE
	AMG	-	1.02 (1)	1.08± 0.02 (4)	1.09 ± 0.06 (5)	1.09 ± 0.02 (3)	1.18 ± 0.13 (4)	1.18 ± 0.06 (7)	1.14 ± 0.15 (9)	1.10 (1)	1.32 ± 0.33 (6)	1.11 ± 0.04 (2)	NE

Table 4.21 demonstrated the shell metric and biomass of identified coral reef gastropods in Pulau Redang such as *ARD, DRG, MRS* and *AMG.* The results showed a significant difference in shell length for both *DRG* and *AMG* among the sampling sites ($p<0.05$). Post hoc Tukey revealed that *DRG* and *AMG* from PL exhibited the highest shell length with 29.63 ± 2.14 mm and 28.10 ± 2.20 mm, respectively. In contrast, the shortest shell lengths were recorded for *DRG* in KB (27.43 ± 2.19 mm) and for *AMG* in TK (14.29±5.31 mm) (Table 4.21). A similar trend was observed in dry weight, where significant differences were found between sites for both species. Post hoc Tukey analysis revealed that the individuals of *DRG* and *AMG* from PL also had the highest dry weights with 4.14 ± 0.61 g and 3.89 ± 0.59 g, respectively. No significant differences were observed in the condition index (*CI*) for *DRG* as the values were relatively consistent across sites ($p>0.05$). However, Post hoc Tukey indicated that *AMG* from TK contributed the highest *CI* value (1.12 ± 0.07) (Table 4.21).

The shell metric and biomass of *MRS* were not evaluated (NE) as only a single individual of the species was found in KB. However, this individual recorded the highest value for shell length (20.95 mm), dry weight (2.16 g) and condition index (1.10) for *MRS* in Pulau Redang (Table 4.21). The lowest shell length and dry weight values for *MRS* were found in TK with 15.69 ± 3.40 mm and 0.84 ± 0.44 g, while the lowest condition index was observed in PL (1.06 ± 0.03). Similarly, *ARD* was not evaluated (NE) as this species was only recorded at a single study site. The shell length, dry weight and condition index for this species were 28.49 ± 7.06 mm, 9.23 ± 6.14 g and 1.10 ± 0.06, respectively (Table 4.21).

Table 4.21 Shell length (mm), dry weight (g) and condition index of coral reef gastropods in Pulau Redang (KB=Pulau Kerengga Besar, PL=Pulau Lima, TK=Terumbu Kili). *ARD*=*Astralium rhodostomum*, *DRG*=*Drupella rugosa*, *MRS*=*Morula spinosa* and *AMG*=*Arakawania marginalba*, total number of individuals (n) and - = none of the gastropods present are also shown.

Metrics	**Species**	**Study sites**			**p-value sites**
		KB	**PL**	**TK**	
Shell length (mm)	*ARD*	-	28.49±7.06 (10)	-	NE
	DRG	27.43±2.19 (41)	29.63±2.14 (14)	28.03±2.02 (57)	F=5.908, p= 0.04 (<0.05) KB<TK<PL
	MRS	20.95 (1)	15.69±3.40 (5)	13.29±4.73 (6)	NE
	AMG	23.03±2.40 (9)	28.10±2.20 (3)	14.29±5.31 (31)	F=17.61, p=3.02E-06 (<0.05) TK<KB<PL
Dry weight (g)	*ARD*	-	9.23±6.14 (10)	-	NE
	DRG	3.55±0.72 (41)	4.14±0.61 (14)	3.73±0.74 (57)	F=3.493, p=0.03 (<0.05) KB<TK<PL
	MRS	2.16 (1)	0.85±0.49 (5)	0.84±0.44 (6)	NE
	AMG	1.96±0.62 (9)	3.89±0.59 (3)	0.55±0.67 (31)	F=21.22, p=4.27E-07 (<0.05) TK<KB<PL
Condition index	*ARD*	-	1.10±0.06 (10)	-	NE
	DRG	1.12±0.24 (41)	1.15±0.14 (14)	1.11±0.13 (57)	F=0.443, p=0.644 (>0.05) TK; KB; PL
	MRS	1.10 (1)	1.06±0.03 (5)	1.08±0.03 (6)	NE
	AMG	1.07±0.01 (9)	1.06±0.02 (3)	1.12 ± 0.07 (31)	F=3.994, p=0.02 (<0.05) PL<KB<TK

The results in Table 4.22 showed no significant ($p>0.05$) and significant ($p<0.05$) differences in shell length (mm), dry weight (g) and condition index for *DRG* in Pulau Tenggol. No significant difference was observed in shell length as the values followed a relatively consistent pattern across sites. However, Post-hoc Tukey revealed that the highest dry weight and condition index of *DRG* was recorded at TP (8.32 ± 0.78 g) and LW (1.09 ± 0.02), respectively. In contrast, the lowest values for dry weight and condition index were observed at LW (3.62 ± 0.82 g) and SN (1.03 ± 0.08) (Table 4.22).

In addition, other species such as *CVL* and *DCR* showed no significant differences ($p>0.05$) in shell length, dry weight and condition index (Table 4.22). Post-hoc Tukey indicated that the shell metrics and biomass values for both species followed relatively similar patterns. Furthermore, *AMG* and *CCR* were not evaluated (NE) for their shell metrics and biomass as each species was only discovered at a single study site. The values for shell length, dry weight and condition index were as follows: *AMG* (29.87 ± 5.34 mm, 2.94 ± 1.35 g and 1.06 ± 0.01) and *CCR* (44.70 mm, 10.28 g and 1.04) (Table 4.22).

Table 4.22 Shell length (mm), dry weight (g) and condition index of coral reef gastropods in Pulau Tenggol (TP=Turtle Point, TR=Teluk Rajawali, RJ=Rajawali, SN=Sri Nakhota and LW=Lost World). *DRG=Drupella rugosa*, *AMG=Arakawania marginalba, CVL=Coralliophila violacea, DCR=Drupella cornus* and *CCR=Cerithium coralium*, total number of individuals (n) and - = none of the gastropods present are also shown.

Metrics	Species	Study sites					p-value sites
		TP	TR	RJ	SN	LW	
Shell length (mm)	*DRG*	35.69 ± 1.28 (2)	-	36.73 ± 0.25 (2)	31.73 ± 3.17 (16)	30.12 ± 2.56 (15)	F=4.664, p=0.083 (>0.05) LW;SN;TP;RJ
	AMG	-	-	-	-	29.87 ± 5.34 (4)	NE
	CVL	-	24.29 ± 9.98 (2)	-	-	21.81 ± 4.78 (3)	F=1.038, p=0.626 (>0.05) LW;TR
	DCR	35.04 ± 2.32 (2)	-	-	-	30.24 ± 4.57 (6)	F=1.575, p=0.202>0.05 LW; TP
	CCR	-	-	-	44.70 (1)	-	NE
Dry weight (g)	*DRG*	8.32 ± 0.78 (2)	-	7.24 ± 0.11 (2)	5.54 ± 1.43 (16)	3.62 ± 0.82 (15)	F=14.29, p=5.06E-06 (<0.05) LW<SN<RJ<TP
	AMG	-	-	-	-	2.94 ± 1.35 (4)	NE
	CVL	-	5.85 ± 4.99 (2)	-	-	4.08 ± 2.10 (3)	F=.01154, p=0.587 (>0.05) LW;TR
	DCR	5.78 ± 1.15 (2)	-	-	-	4.32 ± 1.54 (6)	F=1.255, p=0.228 (>0.05) LW;TP
	CCR	-	-	-	10.28 (1)	-	NE
Condition index	*DRG*	1.07 ± 0.01 (2)	-	1.06 ± 0.04 (2)	1.03 ± 0.08 (16)	1.09 ± 0.02 (15)	F=3.164, p=0.038 (<0.05) SN<RJ<TP<LW
	AMG	-	-	-	-	0.96 ± 0.25 (4)	NE
	CVL	-	1.19 ± 0.04 (2)	-	-	2.16 ± 1.87 (3)	F=0.5852, p=0.561 (>0.05) TR; LW

Cont

	DCR	1.07 ± 0.02 (2)	-	-	-	1.06 ± 0.01 (6)	F=0.857, p=0.658 (>0.05) LW;TP
	CCR	-	-	-	1.04 (1)	-	NE

Based on Table 4.23, the shell metrics and biomass values for *DCR*, *DRG*, *ACY* and *AMG* in Pulau Yu Besar were recorded. There were significant ($p<0.05$) and no significant ($p>0.05$) differences in shell length, dry weight and condition index for *DRG* and *AMG*. For *DRG,* one-way ANOVA showed no significant differences across all study sites in shell length, dry weight and condition index, as post-hoc Tukey revealed relatively similar patterns for these measurements.

In contrast, *AMG* exhibited significant differences ($p<0.05$) in shell length and dry weight, while no significant difference ($p>0.05$) was found in the condition index (Table 4.23). The longest shell (31.25 ± 0.53 mm) and heaviest dry weight (2.98 ± 0.09 g) were documented in S1, indicating significant variation in these parameters. However, the condition index for AMG remained relatively consistent across all sites.

Drupella cornus and *Arakawania ceylonica* were not evaluated (NE) as only one individual presented at each study sites. For *DCR,* the individual from S2 exhibited relatively high values of shell length, dry weight and the condition index. The values were 44.31 mm, 16.99 g and 1.10, respectively (Table 4.23). Meanwhile, *ACY* was found only at S1 with a shell length of 43.41 mm, dry weight of 12.93 g and condition index 1.07 (Table 4.23).

Table 4.23 Shell length (mm), dry weight (g) and condition index of coral reef gastropods in Pulau Yu Besar (S1=Site 1 and S2=Site 2). *DCR=Drupella cornus, DRG=Drupella rugosa, ACY=Arakawania ceylonica* and *AMG=Arakawania marginalba,* total number of individuals (n) and - = none of the gastropods present are also shown.

Metrics	**Species**	**Study sites**		**p-value sites**
		S1	**S2**	
Shell length (mm)	*DCR*	23.29 (1)	44.31 (1)	NE
	DRG	29.50 ± 2.19 (14)	29.06 ± 1.73 (4)	F=0.103, p=0.753 (>0.05) S2; S1
	ACY	43.41 (1)	-	NE
	AMG	31.25 ± 0.53 (2)	15.26 ± 2.48 (3)	F=37.53, p=0.008 (<0.05) S2<S1
Dry weight (g)	*DCR*	3.23 (1)	16.99 (1)	NE
	DRG	3.73 ± 0.80 (14)	3.68 ± 0.47 (4)	F=0.0015, p=0.970 (>0.05) S2; S1
	ACY	12.93 (1)	-	NE
	AMG	2.98 ± 0.09 (2)	0.31 ± 0.09 (3)	F=119.7, p=0.002 (<0.05) S2<S1
Condition index	*DCR*	1.05 (1)	1.10 (1)	NE
	DRG	1.17 ± 0.24 (14)	1.07 ± 0.01 (4)	F=0.817, p=0.387 (>0.05) S2; S1
	ACY	1.07 (1)	-	NE
	AMG	1.11 ± 0.02 (2)	1.11 ± 0.08 (3)	F=0.006, p=0.941 (>0.05) S1; S2

According to Table 4.24, the results displayed the shell length, dry weight and condition index for coral reef gastropods collected in Pulau Yu Kecil. Given a value ($p > 0.05$) for *MRS*, the significance of these three metrics was approved using one-way ANOVA. The values of shell length, dry weight and condition index of this species at Pulau Yu Kecil study sites exhibited a similar trend.

In addition, *Drupella cornus* was not evaluated (NE) because only one individual of this species was found in S3. However, the result indicated that the shell length of this species from S1 was longer (33.55 ± 7.71 mm) compared to S3 (28.47 mm) (Table 4.24). The dry weight and condition index also followed a similar pattern, as the values for both measurements were higher in S1, 9.68 ± 5.89 g and 1.13 ± 0.04 compared to S3, where the dry weight and condition index were only 3.46 ± 0.66 g and 1.06.

Lastly, *D. rugosa*, *A. ceylonica* and *A. marginalba* were categorised as not evaluated (NE) since each species was only discovered in one study site. The values of shell length, dry weight and condition index for *DRG* were 28.06 ± 2.23 mm, 3.46 ± 0.66 g and 1.07 ± 0.09. Meanwhile, the corresponding values for *ACY* were 74.39 mm, 61.85 g and 1.07, while for *AMG* were 26.79 ± 1.90 mm, 1.95 ± 0.46 g and 1.08 ± 0.01, respectively (Table 4.24).

Table 4.24 Shell length (mm), dry weight (g) and condition index of coral reef gastropods in Pulau Yu Kecil (S1=Site 1, S2=Site 2 and S3=Site 3). *DCR=Drupella cornus*, *DRG=Drupella rugosa, MRS=Morula spinosa, ACY=Arakawania ceylonica* and *AMG=Arakawania marginalba,* total number of individuals (n) and - = none of the gastropods present are also shown.

Metrics	Species	Study sites			p-value sites
		S1	S2	S3	
Shell length (mm)	*DCR*	33.55 ± 7.71 (2)	-	28.47 (1)	NE
	DRG	-	-	28.06 ± 2.23 (39)	NE
	MRS	25.35 ± 3.11 (15)	23.82 ± 0.81 (2)	-	F=0.331, p=0.574 (>0.05) S2; S1
	ACY	74.39 (1)	-	-	NE
	AMG	-	26.79 ± 1.90 (11)	-	NE
Dry weight (g)	*DCR*	9.68 ± 5.89 (2)	-	4.58 (1)	NE
	DRG	-	-	3.46 ± 0.66 (39)	NE
	MRS	2.77 ± 0.05 (15)	2.56 ± 0.75 (2)	-	F=0.08, p=0.928 (>0.05) S2; S1
	ACY	61.85 (1)	-	-	NE
	AMG	-	1.95 ± 0.46 (11)	-	NE
Condition index	*DCR*	1.13 ± 0.04 (2)	-	1.06 (1)	NE
	DRG	-	-	1.07 ± 0.09 (39)	NE
	MRS	1.05 ± 0.06 (15)	1.06 ± 0.01 (2)	-	F=0.198, p=0.889 (>0.05) S2; S1
	ACY	1.07 (1)	-	-	NE
	AMG	-	1.08 ± 0.01(11)	-	NE

4.6 Feeding guilds of gastropods in Terengganu marine protected islands

Percentage of feeding guilds among islands

Figure 4.23 showed the percentage of gastropods between Terengganu marine protected islands according to feeding guilds. Based on previous studies, identified gastropods were divided into three feeding guilds namely corallivorous, carnivorous, and herbivorous. PPH ranked the highest value (28.40%) for the corallivorous group. PYB was recorded as the least corallivorous with 20 individuals (3.94%). PPH contained the highest number of carnivorous gastropods with 65 individuals (35.14%), followed by PRD (29.73%) (Appendix 2; A). In contrast, the total number of carnivorous gastropods was lowest in PYB (3.24%) and PTG (2.16%). Most herbivorous gastropods were observed in PRD with 10 individuals (83.33%). Meanwhile, only one individual was recorded at each PPH and PTG.

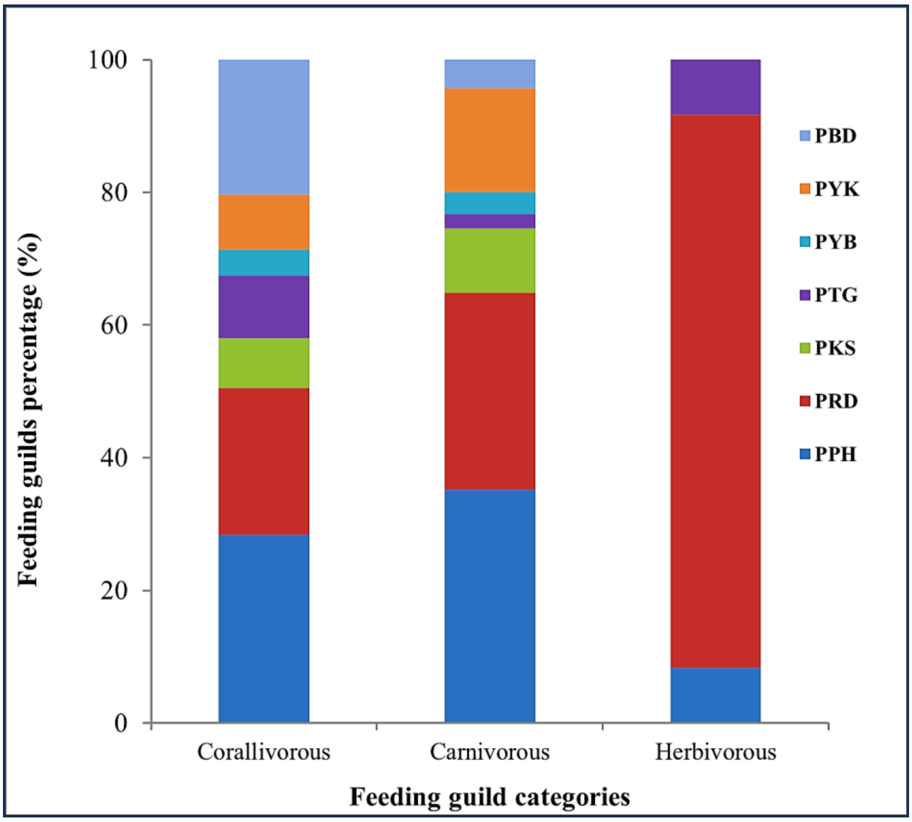

Figure 4.23 Percentage of coral reef gastropods among islands according to feeding guilds (PBD=Pulau Bidong, PKS=Pulau Kapas, PPH=Pulau Perhentian, PRD=Pulau Redang, PTG=Pulau Tenggol PYB=Pulau Yu Besar and PYK=Pulau Yu Kecil).

Percentage of feeding guilds within islands

Figure 4.24 shows the percentage of feeding guilds for gastropods within Terengganu marine protected islands. Each of the islands was dominated by individuals from corallivorous, with PBD (14.63%), PKS (5.40%), PPH (20.45%), PRD (15.91%), PTG (6.82%), PYB (2.84%) and PYK (5.97%). Carnivorous gastropods were the second most abundant species; PBD (1.14%), PKS (2.56%), PPH (9.23%), PRD (7.87%), PTG (0.57%), PYB (0.85%) and PYK (4.12%). The rarest feeding guild recorded was herbivorous and found in PPH (0.14%), PRD (1.40%) and PTG (0.14%). Meanwhile, no herbivorous species were found in PBD, PKS, PYB and PYK (Appendix 2; B).

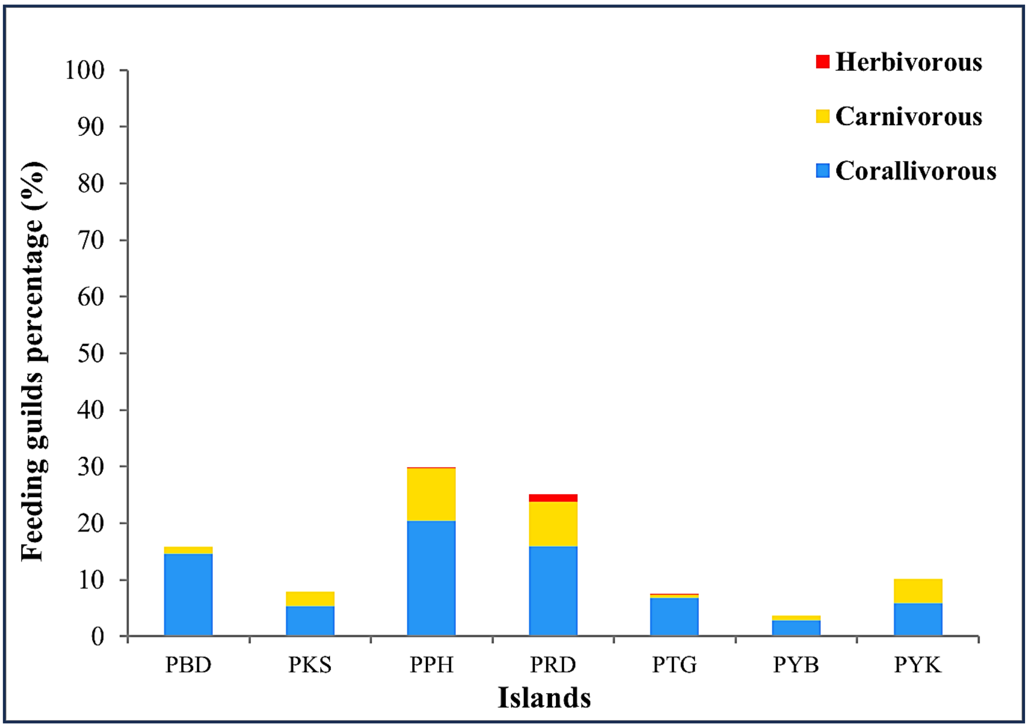

Figure 4.24 Percentage of coral reef gastropods within islands according to feeding guilds (PBD=Pulau Bidong, PKS=Pulau Kapas, PPH=Pulau Perhentian, PRD=Pulau Redang, PTG=Pulau Tenggol PYB=Pulau Yu Besar and PYK=Pulau Yu Kecil).

CHAPTER 5

DISCUSSION

5.1 Distribution and description of coral reef gastropods

The coral reef is a prominent tropical rainforest in the ocean because of their high level of complexity and enormous biodiversity (Apprill et al., 2023; Nama et al., 2023) as it serves as a habitat for myriad marine organisms and holds a significant source of economic and cultural value to humankind (Zhang et al., 2024). The coral reefs globally deteriorated due to severe pollution, overfishing and climatic pressure such as warming oceans since the 1970s (Dutra et al., 2021). Apart from that, coral reef ecosystems were also susceptible to consumers such as fish (Cole et al., 2008), echinoderms (Kroon et al., 2021) and corallivorous gastropods (Kaullysing et al., 2020). The feeding behaviour of corallivorous gastropods not only caused severe tissue loss but also potentially damaged coral reefs by spreading diseases among the coral population (Montano et al., 2022).

In this study, *D. rugosa* from Muricidae is regarded as the most dominant gastropod collected at coral reefs with 479 individuals in all stations. Pulau Perhentian recorded the highest number of *D. rugosa* with 140 individuals. One of the reasons is that Pulau Perhentian covers sampling sites more widely than the other islands. This is because the broader coverage of the island increased the chances of encountering more gastropods during sampling. Apart from that, Pulau Perhentian has a variety of coral reefs including *Acropora* spp. (Hong et al., 2020). *Drupella rugosa* is an obligate and generalist corallivore that feeds exclusively on corals with *Acropora* spp. being among its preferred prey (Sam et al., 2017). However, the reduction in coral cover has only a minimal impact on corallivorous gastropods as this predator demonstrates strong adaptability to modify their feeding preferences in response to the depletion of their preferred corals (Hoeksema et al., 2013; Moerland et al., 2016; Saponari et al., 2021). The mouth of *D. rugosa* is equipped with an external cuticularized proboscis and a radula, which serves to against coral nematocysts and enhance feeding efficiency (Samsuri et al., 2018). *Drupella* individuals are observed to aggregate on damaged corals due to the release of mucus or other secretions by coral colonies that may have contained feeding attractants for the species (Morton et al., 2002; Kita et al., 2005). However, this gastropod is not attracted to coral recruits as *Drupella* insufficiently detects the mucus produced by these corals (Tsang et al., 2018). In addition, some studies suggested that the feeding rates of the *Drupella* genus vary, posing threats to the coral reef ecosystem. Notably, the feeding rates of *D. rugosa* are reported to be higher than *D. cornus* (Samsuri et al., 2018). A study by Sam et al. (2017) in Thailand demonstrates that although *D. rugosa* is smaller in size, its feeding rate is higher with 0.72 cm^2 of coral tissues per day compared to *D. cornus* (0.65cm^2 coral tissue/day).

The present study also revealed that *A. marginalba* is the second most frequently observed with 121 individuals recorded. The species is most abundant in Pulau Perhentian and Pulau Redang. The higher number of individuals may have resulted from the ability of its pelagic larvae to cross large barriers of substrates (Barroso et al., 2020). *Arakawania marginalba,* formerly known as *Tenguella marginalba* is noteworthy for its distinctive characteristics, particularly its high-spired shells, which provided protection against unfavourable conditions (Baharuddin et al., 2019). Additionally, the species is frequently found in rocky pools as this microhabitat provides the potential to mitigate severe environmental conditions (Scheffers et al., 2014). This phenomenon occurs because most gastropods tend to move to habitats with lower heat and desiccation stress when they are not actively engaged in foraging (Schaefer et al., 2023). However, *A. marginalba* is also capable of living in environments such as intertidal zones and coral reef ecosystems. Its distribution is strongly influenced by wave exposure, competitors and the presence of their food resources (Baharuddin et al., 2019; Cahyadi et al., 2021). This species is a generalist carnivore and primarily feeds on gastropods, barnacles, limpets and oysters. It is known for its ability to use the radula by drilling its prey (Wright et al., 2018).

Morula spinosa is the third most abundant gastropod as this species is found at almost all sampling stations except Pulau Tenggol and Pulau Yu Besar. The highest number of species are recorded in Pulau Perhentian and Pulau Yu Kecil. Apart from the higher coverage of sampling sites, the complex coral reef structures in Pulau Perhentian and Pulau Yu Kecil provided many crevices and spaces for species to thrive and hide from predators (Syahrul et al. 2022). *Morula spinosa,* a carnivorous gastropod, mainly feeds on carrion, polychaetes and small molluscs, aligning with the dietary preferences of other muricid gastropod species (Barco et al., 2010). Yokochi (2004) highlighted the early documentation of *M. spinosa* feeding on coral reefs in Japan; however, the species was predominantly considered a coral scavenger rather than a corallivore based on its feeding habits. Although *M. spinosa* occurs in Terengganu marine protected islands, the population and distribution of gastropods are not exclusively dependent on the coral reef (Moerland et al., 2016). This is because the species displayed its capability to exploit a broader range of prey resources. The presence of *M. spinosa* within the coral ecosystem is due to its tendency to inhabit coral reefs as a shelter and feed on small invertebrates such as herbivorous gastropods (Soekendarsi, 2019). The *Morula* genus is commonly involved in feeding behaviours by drilling into sedentary and semi-mobile prey. The drilling behaviour by gastropods is a complex chemo-mechanical process that involves acid secretion from a boring organ located in the foot, along with scraping activity by the radula (Clelland & Webster, 2021).

Compared to *D. rugosa, D. cornus* has fewer individuals with only 23 recorded across Pulau Perhentian, Pulau Tenggol, Pulau Yu Besar, Pulau Yu Kecil and Pulau Bidong. *Drupella cornus* is one of the highly cryptic corallivorous species commonly distributed across tropical reefs in the Indo-Pacific region. Adults of this species predominantly utilize their specialized radula to scrape the living tissue from coral skeletons (Claremont et al., 2011; Haslam et al., 2023). This ectoparasitic gastropod is frequently associated with fast-growing corals (e.g. *Acropora* and *Pocillopora*) and they are also found clustered on slow-growing corals (e.g. *Porites* and *Fungiids*) when their preferred corals are scarce (Schoepf et al., 2010; Hoeksema et al., 2013). Another study suggested that *D. cornus* is regularly found in large aggregations on coral reefs, likely due to the chemical cues released by damaged corals and conspecifics (Hamman, 2018). However, in the present study, the lower number of *D. cornus* recorded across the islands may have been due to its tendency to inhabit exposed corals, whereas *D. rugosa* predominantly occupies submerged coral reefs (Zhang et al., 2024). The reduction in the number of *D. cornus* is related to the fact that most sampling in this study is conducted in the submerged coral reef areas.

A total of 10 individuals of *A. rhodostomum* from the Turbinidae family are observed in Pulau Redang. Compared to the other islands, the presence of this species in Pulau Redang indicates the presence of high algae in the coral ecosystem. This is attributed to the fact that *A. rhodostomum* is a conspicuous herbivore that is commonly found in subtidal coral reef ecosystems (Zainuddin et al., 2024). *Astralium rhodostomum* is also widely recognized throughout the Pacific region, spanning from Thailand to southeastern Polynesia (Meyer et al., 2005). The population and size distribution of this turbinid gastropod on intertidal reefs also undergo alterations across environmental gradients associated with elevation changes (Worthington & Fairweather, 1989; Bruton et al., 1991). The shell of *Astralium rhodostomum* is usually covered with algae, allowing the gastropods to camouflage themselves well from threats (Isroni et al., 2023).

Only five individuals of *Coralliophila violacea* from Muricidae are found in Pulau Tenggol. The presence of *C. violacea* in Pulau Tenggol could have been attributed to the dominance of *Porites* in the area (Hong et al., 2020). *Coralliophila violacea* is known as a muricid corallivorous gastropod that exhibits obligate relationships with corals, particularly *Porites*. This gastropod is also distributed in shallow tropical and subtropical Indo-Pacific regions (Gautrand et al., 2023). The primary food resources of this gastropod were coral polyps, coral mucus and zooxanthellae algae (Gautrand et al., 2023). *Coralliophila violacea* inserted its proboscis into coral polyps as it lacks both jaws and a radula to extract the food. It remains associated with the same coral host for several months and was considered a prudent sessile species (Oren et al., 1998). Oren et al. (1998) documented that *C. violacea* created a carbon sink (translocated carbon) from surrounding tissue to the injured areas to promote the healing process and provided a continual food supply for extended periods. The feeding behaviour of *C. violacea* harms coral reefs by destroying underlying tissue and leaving scars on coral skeletons (Raymundo et al., 2016). The formation of a carbon sink also reduces the resources available for coral regeneration as most energy is used to repair injured areas (Hamman, 2018). When their food resources are depleted, they move to new habitats and form new aggregations on different coral hosts (Hamman, 2018).

Apart from *A. marginalba,* the other *Arakawania* species identified in Terengganu marine protected islands is *A. ceylonica* with one individual recorded at both Pulau Yu Kecil and Pulau Yu Besar. *Arakawania ceylonica*, formerly known as *Tenguella ceylonica* is known to occur in areas such as India, Sri Lanka, Indonesia, Thailand, Philippines and Malaysia (Mujiono, 2020; Fasila et al., 2024; Ghatpande et al., 2024). They are generally abundant on intertidal rocky shores, playing an ecologically important role as predators (Barco et al., 2010). *Arakawania ceylonica* is a carnivore as it feeds on molluscs, barnacles and other varieties of prey. *A. ceylonica* was predominantly observed within rocky crevices and oyster beds, typically at depths ranging from 0 to 1 metre (Ghatpande et al., 2024). The presence of *A. ceylonica* in the coral ecosystem in Pulau Yu Besar and Pulau Yu Kecil is caused by larvae settlement. This is because the larvae of gastropods had a greater influence on gastropod distribution than adults as they were capable of crossing large barriers of the substrate (Barroso et al., 2022). The short distance between Pulau Yu Besar and Pulau Yu Kecil also contributes to the occurrence of the same species in both islands.

Cerithium coralium from the Cerithiidae family was among the least species recorded in Pulau Tenggol with only one individual observed. *Cerithium coralium* was typically found in mangrove areas but its distribution extended to other marine habitats as well (Barnes, 2003). Some cerithiid gastropods are recognised as herbivores and they primarily inhabit intertidal zones or shallow waters, which provide abundant preferred resources for them (Sun & Zhang, 2014). *Cerithium coralium* was widely distributed in Australia, New Guinea, Japan, the Philippines, the Gulf of Thailand and Indonesia (Ilias et al., 2021).

Another of the least gastropod species was *C. columna*, which was found in Pulau Perhentian. *Cerithium columna* is known to inhabit seagrass and intertidal zones (Taylor, 1968). This gastropod also occurs in the subtidal zone, which helps to retain water and avoid fluctuations in temperature for gastropods as this species is unable to thrive in harsh physiochemical conditions (Ayal & Safriel, 1982). However, *C. columna* prefers to inhabit tide pools within the intertidal zone that are well-developed with algae as Cerithiidae gastropods are herbivores (Ayal & Safriel 1982; Sun & Zhang, 2014). Although most cerithiid gastropods inhabited intertidal areas, the presence of one individual each of *C. coralium* and *C. columna* in the coral reef areas of Pulau Tenggol and Pulau Perhentian may have resulted from strong currents and waves that displaced them from their original habitat (Basir et al., 2022).

5.2 Diversity, distribution and abundance among islands

Species diversity is a component of species richness and evenness where the individuals are dispersed in a community (Sharif et al., 2017). Rich environments in Malaysia such as Terengganu boast rich coastal habitats including mangroves (Azmi, 2014), seagrasses (Zakaria et al., 2003) and coral ecosystems (Safuan et al. 2022), which potentially attract more variation of animal species. The species diversity of gastropods associated with coral reefs in Terengganu marine protected islands depends on coral cover. This is because the coral reef ecosystem is considered one of the paramount factors influencing the diversity and abundance of gastropods in the marine environment (Mohanraj et al., 2015). Since most marine gastropods are very closely associated with the coral reefs for food, shelter or reproduction, it is imperative to prioritize the protection of the coral ecosystem to ensure the conservation of gastropods (Mohanraj et al., 2015).

Based on the findings of this study, the results showed that Terengganu marine protected islands harbour a low diversity of coral reef gastropods (Table 4.2). The high diversity of gastropods is correlated with a high diversity of life forms in the coral (Barrientos-Luján et al. 2017). However in early January 2019, the Tropical Pabuk Storm emerged in the South China Sea and affected Peninsular Malaysia, including Terengganu, which experienced post-effects from the storm (Shariful et al., 2020). Consequently, surveys indicated that most of the coral reefs in Terengganu marine protected islands were in ‘fair’ (<50% and >25%) and ‘poor’ (<25%) conditions due to the storm’s effect (Chou et al., 1994; Hong et al., 2020).

In comparing diversity among islands, PYK (*H'*=1.154) exhibited higher values of the Shannon index (Table 4.2). The high value of the diversity index in islands is potentially due to a higher percentage of preferred corals such as branching corals that harbour a more significant number of gastropods as the volume of head coral and spaces within branches serve as habitat and provide protection for them to against waves and predators (Bachok et al., 2021; Barrientos-Luján et al., 2021). Simpson's index (*D*) was deemed low as most values fall below one. Previous research suggested that as the value of *D* increases towards higher values, the diversity will decrease (Shah & Pandit, 2013).

Margalef index has no limit value and varies depending on the number of species. A higher value of *Ma* indicated a higher species richness. The index allows researchers to compare the species richness across different study sites (Shah & Pandit, 2013). Menhinick index also aims to estimate the species richness but remains independent of the sample size (Shah & Pandit, 2013). According to Hossain et al. (2017), higher diversity values such as species richness indicate the suitability of habitat for the organism's survival and are reported to correlate with longer food chains and more complex food webs. However, in the present study, the values for both indices were considered low as most were below one. The low values for both *Ma* and *Me* indices may be attributed to the limited number of species found, as well as environmental degradation resulting from anthropogenic and natural factors such as the tropical Pabuk storm that hit Terengganu marine protected islands (Shah & Pandit, 2013; Hong et al., 2020).

The evenness index is used to describe the community condition in the ecosystem based on how equally individuals are distributed among the species. According to Krebs (1972), values closer to 1 indicate that the individuals between species are relatively similar (very equal), while values closer to 0 indicate more variation in species. In the present research, J' and Ep indices indicate that the lowest scores were recorded in PBD. Following evenness criteria, the results from PBD suggest that the reef gastropods' community structure falls within the 'fairly equal' and 'poor' categories.

Based on Figure 4.10, the total sampling efforts were still inadequate to document the total diversity of gastropods in Pulau Tenggol, Pulau Yu Besar and Pulau Yu Kecil as the cumulative curves in these sampling sites remained exponential (Munian et al., 2020). Pulau Perhentian experienced rapid increases in reaching the asymptote curve. The island also covered the highest number of sampling sites compared to other islands; therefore the possibility of recording the individuals increases. As the number of individuals observed increased, more species could be recorded during sampling (Shafie et al. 2023). However, the rarefaction curve at the study location eventually began to level off, indicating that the same species were repeatedly being sampled. In Pulau Redang, Pulau Kapas and Pulau Bidong, the curves approached an asymptote, suggesting that the species diversity in locations may have been adequately identified. Therefore, the sampling was considered complete as the discovery of new or rare species had gradually declined (Azman et al., 2019).

5.3 Species abundance distribution

The high abundance of coral reef cover in Terengganu marine protected islands may contribute to the high species richness of coral reef gastropods. This is corroborated by this study where the most common species were *D. rugosa* with 479 individuals, followed by *A. marginalba* as the second most abundant with 121 individuals, respectively (Figure 4.12). During the survey of study areas, the coral reefs most commonly observed in Terengganu marine protected islands were dominated by *Acropora* and *Porites* genera.

Acropora coral is regarded as one of the fastest-growing corals with some species capable of extending by 20-30 cm per year. Many species of this genus exhibit high morphological plasticity in response to environmental conditions, allowing them to thrive in a broad range of habitats and turbulence regimes (Mercado-Molina et al., 2020). Their rapid growth and morphological plasticity provide *Acropora* species with a competitive advantage in colonizing the substrates under favourable conditions (Mercado-Molina et al., 2020). This rapid growth also makes acroporids significant contributors to reef accretion and a vital functional group in maintaining reef functionality. In contrast, *Porites* corals grow more slowly with radial growth rates ranging from 5-20 cm. However, this genus possesses a stronger skeleton structure to resist high-energy forces from waves and current actions (Akmal et al. 2019). Therefore, the dominance of *Porites* is likely due to their ability to tolerate harsh environmental conditions such as strong currents, wave actions and sedimentation loads (Akmal et al. 2019).

The higher number of *D. rugosa* at all sampling stations indicated a greater abundance of preferred corals, particularly *Acropora*. The aggregations of the *Drupella* gastropods are commonly found on *Acropora,* possibly due to its larger surface area and higher protein content. In addition, the preference for *Acropora* corals by corallivorous gastropods may be linked to their selective feeding on damaged tissue. Since *Acropora* is prone to damage, the increased mucus secreted by injured corals will attract predators (Zhang et al., 2024). This vulnerability arises because *Acropora* spp. allocated more energy to growth than defence mechanisms, making them less resistant to predation and diseases (Zhang et al., 2024). However, the higher number of *D. rugosa* also correlated with their feeding plasticity and exhibited a dietary shift towards less preferred prey corals such as *Porites* (Bruckner et al., 2017).

Arakawania marginalba was identified as the second most dominant gastropod because this species was known to inhabit a wide range of marine habitats, although this muricid whelk falls under the carnivorous category (Baharuddin et al., 2019). *Cerithium columna* and *Cerithium coralium* were considered rare species with singletons for each because most of the Cerithiidae family are typically found in intertidal areas where their resources are more abundant (Sun & Zhang, 2014). Similarly, *Arakawania ceylonica* was categorised as a rare species with doubletons as this species is commonly abundant at intertidal rocky shores. Therefore, the presence of these three species within the coral ecosystems is probably due to strong ocean currents and waves generated by the Pabuk storms, which may have drifted the individuals away from their origin into the reef area.

5.4 Diversity, distribution and abundance within islands

Gastropods are a notable group of invertebrates that belong to the phylum Mollusca. They are among marine biotas that exhibit high species diversity and are widespread across various marine habitats (Sukawati et al., 2018; Suyadi et al., 2021). Each gastropod species is adapted to its specific ecological niche, enabling it to thrive under various environmental conditions such as nutrition availability, substrate type and interactions with other species (Sujarta et al., 2022). Variations in these environmental conditions influence gastropods' habitat preferences, leading them to occupy habitats that fall within their tolerance limits (Zaidi et al., 2021; D'Souza et al., 2022; Hilmi et al., 2022). These environmental factors contribute to differences in lifestyle, behaviour and distribution among gastropod species (Sujarta et al., 2022).

5.4.1 Pulau Bidong

Coral reef gastropods recorded in this study revealed that four species from Muricidae were discovered in Pulau Bidong (Table 4.3). *Drupella rugosa* was primarily observed feeding on branching corals and the waters surrounding Pulau Bidong boasted a diverse array of coral forms, spanning from branching to massive coral reefs (Hoeksema et al., 2013; Firdaus et al., 2021). However, Pulau Bidong has experienced a declining trend in live coral cover, decreasing from 47.9% to 28.75%, while the proportion of dead corals increased from 26.3% to 65.09% (Safuan et al., 2020). On the east coast of Peninsular Malaysia, the physical disturbances associated with the northeast monsoon are known to alter coral communities in the region (Toda et al., 2007).

Besides the harsher environmental conditions of the northeast monsoon compared to the southwest monsoon (Roseli & Akhir, 2014; Roseli et al., 2015), coral mortality notably increased following storm-induced disturbance in early 2019. During the storm event, cyclonic wind speeds exceeding 50 mph were detected near the east coast of Peninsular Malaysia, resulting in intensified currents surpassing 1 m/s and wave heights over 4 m. These environmental conditions were more severe than those observed during the normal northeast monsoon (Safuan et al., 2020). The absence of *D. rugosa* and the presence of only a single individual for *D. cornus* in DLT suggests that extreme hydrodynamic conditions may have destroyed most of the coral reefs in area. Furthermore, the destruction and loss of coral habitats particularly branching corals that serve as food sources could lead to local extinction or population declines of these gastropods (Kurniawan et al., 2023).

The other gastropods such as *M. spinosa* and *A. marginalba* were found only at PPC where Safuan et al. (2020) reported that the reef conditions at 8-metre depth in PPC were classified as ‘fair’. These coral reefs may serve as a refuge or microhabitat that buffers against storm impacts (Fraser et al., 2021). Moreover, this finding is also supported by the study's sampling approach, which SCUBA divers conducted surveys within coral reef areas at depths ranging from 3 to 12 metres.

The diversity and richness of coral reef gastropods in Pulau Bidong were relatively low as a result of the Pabuk storm that hit the island (Table 4.4). During regular periods, seasonal winds, precipitation patterns and wave directions are influenced by changes in the current circulation surrounding Pulau Bidong (Daud & Akhir, 2015; Shariful et al., 2020). However, on 4 January 2019, wind speeds reached up to 75km/h as the storm passed across the Gulf of Thailand. Malaysia, including Pulau Bidong has experienced the effects of the storm. The effects were visible on the beaches where dead corals were observed covering rocky shores and sandy regions (Basir et al., 2022). Such disturbances negatively affect gastropod diversity and richness within coral reefs, contributing to uneven species distribution. In addition, the Evenness Index (J’) in DLT and PPK indicated complete evenness and a highly uniform community structure with the categorisation of ‘very good’ (Krebs, 1972). The similarity in the number of individuals between the species in DLT and PPK could be explained by the adequate food availability, which may have reduced competition and supported a more even distribution of individuals among species (Watz & Nyqvist, 2022).

5.4.2 Pulau Kapas

A total of 56 gastropods representing three species (*D. rugosa, M. spinosa* and *A. marginalba*) from the Muricidae family were documented in Pulau Kapas (Table 4.5). ST yielded the highest number of *D. rugosa* and *A. marginalba* individuals compared to KT and TJ as the coral reefs in ST were categorised as being in 'good' condition. Meanwhile, coral reefs in KT and TJ were classified as being in 'fair' and 'poor' condition, respectively (Chou et al., 1994; Bachok et al., 2021). Despite being categorised as 'fair' and dominated by branching corals, KT recorded only three individuals of *D. rugosa* and two of *A. marginalba*. Some gastropods could not be collected due to their cryptic position within coral structures, where the arrangement of coral branches hindered their detection and assessment during sampling (Bachok et al., 2021).

The small number of *M. spinosa* found in TJ indicated that the coral reef condition was 'poor', with live coral cover less than 25% (Hong et al., 2020). In addition to the Pabuk storm that struck the east coast islands of Terengganu in early 2019, tourism activities also contributed to the destruction of coral communities in Pulau Kapas. Pulau Kapas is renowned for its tourism industry, which promotes water sports activities such as snorkelling and diving to attract tourists. These activities are the most popular attractions on the island and have contributed to the annual increase in tourist numbers (Jaafar & Maideen, 2012). However, improper snorkelling activities by tourists can physically damage coral reefs, leading to coral mortality and allowing non-reef-building organisms to colonise reefs (Safuan et al., 2021). Due to the harsh environmental conditions characterised by strong currents and rough seas, no *M. spinosa* individuals could be collected in KT and TJ at that time. This situation may be attributed to Malaysia being affected by monsoonal systems such as the northeast and southwest monsoons. The transition period between these systems (southwest to northeast) occurred in September 2020 (Safuan et al., 2020). The northeast monsoon's environmental conditions are more intense than the southwest monsoon (Roseli & Akhir, 2014; Roseli et al., 2015), making it challenging for divers to assess sampling sites and collect gastropods.

Based on the overall evaluation done in Pulau Kapas, the diversity of gastropods within coral reefs on the island is considered low (Table 4.6). This is unsurprising as only three species of reef gastropods were recorded on the island. The tourism industry has led to physical damage to coral reef communities by improper diving and snorkelling. This event has increased coral mortality and caused dead corals to accumulate (Safuan et al., 2021), resulting in fewer gastropods being found in the coral areas. When comparing species evenness among sites in Pulau Kapas, KT exhibited the highest value, approaching complete evenness as both values were closer to one than those of ST and TJ (Table 4.6). The reef gastropod community in KT was more evenly distributed and categorised under very good conditions.

5.4.3 Pulau Perhentian

Pulau Perhentian contributed 210 individuals from five species, namely *D. cornus, D. rugosa, M. spinosa*, *A. marginalba* and *C. columna* (Table 4.7). *Drupella rugosa* contributed the most abundant with 140 individuals, followed by *A. marginalba* and *M. spinosa* with 42 and 23 individuals, respectively. During the survey, Pulau Perhentian exhibited a low percentage of live coral covers due to strong currents, which severely affected coral reefs (Hong et al., 2020). Although *Porites* dominated most sites in Pulau Perhentian compared to *Acropora*, *D. rugosa* still exhibited the highest abundance. This is attributed to the species' dietary flexibility to shift its preferences from the most favourable corals such as *Acropora* to less preferred corals, *Porites* spp. (Bruckner et al., 2017). However, the abundance of other coral reef gastropods was lower than *D. rugosa*, likely due to the severe impact of the Pabuk storm. This event resulted in a significant percentage (29.28%) of coral mortality with dead corals predominantly covered by algae (Hong et al., 2020). Coral reef recovery from tropical storm can take decades to centuries when the physical structures are severely damaged or other disturbances impede the recovery process (Dixon et al., 2022).

Among the sites in Pulau Perhentian, PR2 recorded the highest number of individuals with *D. rugosa* dominating the area. PR1 and PRN were also recorded *D. rugosa* as the most observed species. *Acropora* typically constitutes over 50% of coral composition and plays a significant role in Terengganu's coral formation (Safuan et al., 2021). However, a decline in the percentage of this genus may be attributed to physical disturbances such as intense and harsh wave action, making *Favia* and *Goniastrea* corals the second most dominant in Pulau Rawa after *Diploastrea* (Hong et al., 2020). Although *D. rugosa* is observed feeding on small polyps and branching corals like *Acropora*, its prey selectivity depends on the relative abundance of coral species (Hoeksema et al., 2013). Morton and Blackmore (2009) reported a study from Hong Kong where *D. rugosa* shifts its diet to encrusting corals such as *Favia* and *Goniastrea* when branching corals are unavailable. Other coral reef gastropod species observed in Pulau Rawa included *D. cornus, M. spinosa* and *A. marginalba.* The presence and predatory behaviour of these gastropods on coral reefs align with their classification in the Muricidae family, indicating an adaptation to their prey consumption (Zainuddin et al., 2024). *Cerithium columna* was exclusively found in PR1 as the Cerithiidae family primarily inhabits intertidal areas. Its presence could be attributed to a dense layer of macroalgae on the coral reef surface. Additionally, strong wave actions generated by the Pabuk storm that frequently splash across the intertidal zone may have displaced this gastropod into the coral ecosystems as these storms can cause it to drift away due to high-energy storm wave environmet (Basir et al., 2022).

Other sampling sites such as DLG, SBL, PSB, TTG and BNS contributed 16, 15, 14, 12 and 6 individuals from Muricidae, respectively. *Drupella rugosa* was predominantly found in the coral ecosystem, especially in sites like DLG, TTG and BNS where *Porites* spp. was the dominant coral (Hong et al., 2020). Large aggregations of *Drupella* were mostly found on the competitively dominant coral taxa such as *Acropora*. In addition, this genus offers a larger surface area and higher tissue content compared to the other coral families. Nevertheless, following a notable reduction of acroporids due to catastrophic events, *Drupella* displayed a dietary shift by extending its prey selection towards subdominant corals genera such as *Astreopara, Montipora* and *Porites* (Bruckner et al., 2017).

In Seabell, only a few individuals of *D. rugosa* were observed as the most dominant coral in this site was *Platygyra* (Hong et al., 2020). A study by Tsang and Ang (2019) in Hong Kong found that *Platygyra* fragments were unattractive to *Drupell*a gastropods. This corallivore typically prefers temperature-stressed corals over non-stressed corals (Morton et al., 2002). Despite the higher seawater temperature during the sampling period (30.09°C), *Platygyra*'s tolerance to warmer seawater may explain why *Drupella* did not prefer this coral genus (Tsang & Ang, 2019). Additionally, *Platygyra* possesses defensive tentacles with nematocysts that deter *Drupella* predation (Tsang & Ang, 2019). However, environmental stress may impair nematocyst function, potentially allowing *Drupella* could break through this defence and feed on coral (McIlwain & Jones, 1997). Although only a small number of carnivorous gastropods such as *M. spinosa* and *A. marginalba* were recorded in SBL, their presence may be linked to the 'fair' percentage (22.63%) of invertebrates reported at this study site (Hong et al., 2020).

The presence of 14 individual gastropods from four species such as *D. cornus, D. rugosa, M. spinosa* and *A. marginalba* were documented in PSB, which is situated between TBS and TTG. The number of *D. rugosa* was higher than other species, likely due to the dominance of *Porites* spp. in both TBS and TTG. The presence of corallivorous gastropods also supports the possibility that *Porites* corals dominate PSB, given that coral reefs in this area are known to form patchy coral communities (Tsang & Ang, 2019; Hong et al., 2020). Additionally, a study reported that tropical coral reefs could flourish under suboptimal environmental conditions that are close to their tolerance limit (Perry & Larcombe, 2003). In TPH, 10 individuals of *D. rugosa* were recorded, indicating the presence of preferred corals in the study area. No coral reef gastropods were documented in CBY and TTG as both locations are primarily characterised by boulders and sandy beaches rather than coral reef habitats.

The Shannon diversity index (*H'*) values for all sites in Pulau Perhentian suggested that species richness was lower as most values of *H'* were below 2 (Table 4.8). According to Baharuddin et al. (2019), the *H'* value of 1 indicates severe pollution, values between 1 and 3 indicate moderate pollution and values exceeding 3 suggest no pollution. Therefore, Pulau Perhentian is categorised as moderately polluted. It is important to note that the island is a popular tourist destination. Therefore, anthropogenic pressures from tourism development contribute to sedimentation and nutrient enrichment through river runoff from the mainland and wastewater discharge, influencing coral reef dynamics in the study area (Safuan et al., 2021). Among all the study sites in Pulau Perhentian, PRN recorded the highest diversity values (*H'*=1.494, *D*=0.750, *Ma*=1.542 and *Me*=1.512). Although PRN had the second lowest number of individuals, it recorded a higher number of species with four out of the five species found in Pulau Perhentian. The muricid gastropods found in PRN are known to inhabit a wide range of coastal and marine habitats, including coral reefs. Based on surveys done during the study, TPH also contributed a higher proportion of favourable branching coral reefs, which consequently contributed to a greater abundance of gastropods (Pisapia et al., 2020). Therefore, the occurrence of these gastropods in TPH is justifiable. However, gastropods tend to exhibit cryptic behaviour, mak them more difficult to detect and may result in their low observed abundance (Shin & Allmon, 2023). The findings suggest that the community structures of gastropods across sites in Pulau Perhentian are relatively similar. This result indicates that when a community contains many species of a similar type, it tends to exhibit a higher level of diversity (Baharuddin et al., 2019).

5.4.4 Pulau Redang

In Pulau Redang, 177 individuals from four species of coral reef gastropods were identified (Table 4.9). Among these species, *D. rugosa* stood out as the most abundant with 112 individuals, making up a significant proportion of the overall samples compared to *A. marginalba, M. spinosa* and *A. rhodostomum*. *Drupella rugosa* is known for its widespread presence and commonly found in coral reef ecosystems (Cumming, 2009). According to observations made during surveys, Hong et al. (2020) documented that the most abundant corals found in Pulau Redang were *Acropora* (34.37%), *Porites* (15.81%), *Fungia* (15.40%) and *Pocillopora* (13.63%). Kim (2013) also reported that *D. rugosa* preferred branching corals, particularly *Acropora*, followed by *Pocillopora* and *Montipora*. In 2016, researchers from Universiti Malaysia Terengganu (UMT) documented a significantly higher count of 401 *D. rugosa* individuals at similar current study sites, including Chagar Hutang (CH) and Mak Simpan (MS) or Mak Cantik (MC) (Baharuddin et al., 2017). However, the Pabuk storm was detected in the southern South China Sea and Peninsular Malaysia, with Terengganu experiencing its aftermath in early January 2019 (Shariful et al., 2020). Tropical storms are among the most severe physical disturbances to coral reefs (Lugo-Fernández et al., 2004), primarily due to the intense winds generated by Pabuk, resulting in severe damage to coral ecosystems. This damage included the breakage of branching corals, dislodgment, the removal of large reef colonies and sediment burial, ultimately leading to coral mortality (Beeden et al., 2015; Safuan et al., 2020). Findings by Lee et al. (2020) indicated that some sites in Pulau Redang experienced a decrease in live coral cover including branching corals, following the impact of the Pabuk storm. Hence, this scenario has notably affected *D. rugosa*, which primarily preys on branching coral. The observed decline in this population is likely due to the depletion of food and shelter caused by the tropical storm in this coral ecosystem (Zainuddin et al., 2024). Moreover, the aftermath of such disasters can trigger intraspecific competition among *D. rugosa* adults for limited resources (Zainuddin et al., 2024). In this context, the dominance of adult individuals over the limited food and space sources may result in higher mortality rates among juveniles and intermediates. It is also worth mentioning that *D. rugos*a typically lays its egg capsules on exposed coral skeletons (Sam et al., 2017). However, the coral disruption caused by the Pabuk disaster is likely to affect the reproductive behaviour of this corallivore as the altered post-storm environment may not provide suitable conditions for them to reproduce during their spawning months (Zainuddin et al., 2024).

Arakawania marginalba was the second most abundant species discovered in Pulau Redang with 43 individuals. The distribution and abundance of *A. marginalba* are patchy and commonly occur at low intertidal habitats where prey availability is highest (Moran, 1985). In addition, the presence of *A. marginalba* extends beyond intertidal zones to various depths within tropical and subtropical oceans, including environments such as coral reefs (Cahyadi et al., 2021). However, the Pabuk storm striking Pulau Redang may have caused certain gastropod species to be crushed or washed away by massive storm waves. As a result, this natural event can induce shifts in local biodiversity and potentially alter biological habitat provisions such as coral reefs (Basir et al., 2022). Most of *A. marginalba* were found in TK, amounting to 31 individuals. This muricid whelk has been observed to avoid unfavourable environments such as strong wave exposures. TK had the highest percentage of most favourable coral branches for gastropods such as *Acropora* and *Pocillopora* compared to KB and PL (Hong et al., 2020). Therefore, they tend to seek refuge and shelter within branching corals due to the structural complexity and increased spaces among the branches, which play a crucial role in offering protection against predators (Samsuri et al., 2018).

Observations of *M. spinosa* in Pulau Redang were limited to just 12 individuals, attributed to the fact that this carnivorous gastropod primarily feeds on alternative prey sources such as carrion, polychaetes and small molluscs (Barco et al., 2010). Although Lee et al. (2020) observed a reduction of preferred corals as an outcome of the Pabuk storm, the abundance and population of *M. spinosa* do not solely depend on the coral reef ecosystems (Moerland et al., 2016). This stems from the fact that the species does not exclusively rely on coral reef consumption, demonstrating its capability to utilize alternative prey sources (Titlyanov & Titlyanova, 2009). *Astralium rhodostomum* from the Turbinidae family is recognised as a prominent algae-eating gastropod in reef ecosystems and was predominantly found in Pulau Lima. This is attributed to Pulau Lima having a high percentage of algae-dominated coral area coverage (>85%) compared to KB (52%) and TK (59%) (Lee et al., 2020). No gastropods were observed in CH and MC due to a significant decline in live coral cover following the Pabuk storm (Lee et al., 2020).

In regard to species diversity in Pulau Redang, the ecological indices derived suggest that the diversity of gastropods was relatively low (Table 4.10). The Shannon index can be interpreted according to the classification mentioned by Zainuddin et al. (2024). A value below 1 indicates significant pollution, a value between 1.0 and 3.0 suggests moderate pollution, while a value above 3.0 represents a non-polluted environment. Based on this index, Pulau Redang is categorised as moderate pollution. The diversity analysis may have been influenced by natural physical disturbance, which caused damages and led to subsequent declines in coral reef populations (Lee et al., 2020). However, at both PL and TK in 2020, the Evenness (J’) and Equitability (Ep) indices indicated a high level of species evenness (Table 4.10). Gastropods from the Muricidae family often aggregate together to conserve water and body moisture, thereby preventing dehydration (Zhang et al., 2016). Therefore, these behavioural traits aid murex snails to adapt and survive in challenging environments (Baharuddin et al., 2018).

5.4.5 Pulau Tenggol

In Pulau Tenggol, it was observed that species from the genus *Drupella*, *D. rugosa* had the highest number of individuals (35) compared to other coral reef gastropods. Meanwhile, *C. coralium* recorded only one individual (Table 4.11). LW and SN exhibited the highest abundance of *D. rugosa* compared to TP, TR and RJ, with the coral reef ecosystems being dominated by the *Porites* (Hong et al., 2020). *Drupella*'s feeding preferences have been observed to adapt based on the relative abundance of different coral taxa (Morton & Blackmore, 2009). Although *D. rugosa* is noted to be less attracted to *Porites* spp., these corallivores are recognised as generalist predators capable of shifting their diet in response to changes in the availability of their preferred coral prey, especially when their preferred corals are absent or have declined due to catastrophic disturbances (Hoeksema et al., 2013). This behaviour has also been demonstrated in a study conducted in the Maldives, where researchers observed that most *D. rugosa* tended to aggregate on less preferred corals such as *Porites* when their preferred corals were not available (Bruckner et al., 2017).

Other gastropod species such as *D. cornus* and *A. marginalba* were predominantly observed in LW, where the *Acropora* spp. was the second most abundant coral species in the area (Hong et al., 2020). The complex structures of *Acropora* corals provide ample hiding spaces for gastropods to avoid predators and also offer a high percentage of living tissue for corallivores to feed on. The presence *of C. violacea* in both TR and LW highlights its ecological preference for slow-growing corals such as *Porites* spp. (Oren et al., 1998) as this coral exhibited the highest percentage among all reefs in these two sites (Hong et al., 2020). *Cerithium coralium* was exclusively found in SN where the percentage of algae dominating coral reefs was the highest among all sites in Pulau Tenggol (Hong et al., 2020). However, limitations arose in surveying some sites due to strong currents during the sampling period. Consequently, the uneven distribution of sampling sites around Pulau Tenggol resulted in the collection of gastropods.

The results of the present study suggested that the low number of species led to low diversity and richness of coral reef gastropods in Pulau Tenggol (Table 4.12). Although the coral reefs in Pulau Tenggol were reported to be among the healthiest (Hong et al., 2020), this condition does not necessarily promise high gastropod diversity. Pulau Tenggol is a popular island with deep water that attracts more megafauna such as whale sharks, than other islands. The environmental conditions surrounding the island are naturally harsher compared to other marine protected islands in Terengganu. Therefore, these conditions limited gastropod collection efforts, resulted in the low species diversity and richness observed.

5.4.6 Pulau Yu Besar and Pulau Yu Kecil

Four species of gastropods from Muricidae family were found in both Pulau Yu Besar. The results can be observed in Table 4.13 and Table 4.15. At both locations, *D. rugosa* was the predominant gastropod species observed with higher abundances recorded at S1 (Pulau Yu Besar; 14) and S3 (Pulau Yu Kecil; 39), respectively. This observation suggests that S1 and S3 had a higher percentage of coral reefs, particularly *Acropora* genus (Bachok et al., 2021).

In Pulau Yu Besar, species such as *D. cornus* and *A. marginalba* were predominantly observed in S1. This occurrence is attributed to the reef conditions in the area, which were categorised as 'fair' with live coral cover ranging from 50% to 25% (Rizmaadi et al., 2018). The live coral cover percentage evaluation follows the methodology outlined in the ASEAN-Australia Living Coastal Resource Project (Chou et al., 1994). Although *D. rugosa* is recognised as a prominent species within coral reef ecosystems, only four individuals of this ectoparasitic gastropod could be found at Station 2 of Pulau Yu Besar. This occurrence may be attributed to the high percentage of dead corals in the area, reaching up to 50% (Bachok et al., 2021).

Furthermore, gastropods were absent in S3 of Pulau Yu Besar due to adverse environmental conditions characterised by rough waves, making it challenging for divers to collect specimens during the sampling period.

Meanwhile in Pulau Yu Kecil, S3 recorded the highest number of individuals due to its highest percentage of live coral cover (44%) and the lowest percentage of dead corals (14%). In contrast, S2 had the lowest number of gastropods, possibly due to the highest percentage of coral mortality (Bachok et al., 2021). The presence of the same species in both Pulau Yu Besar and Pulau Yu Kecil could be explained by the close proximity between the two islands. *Arakwania ceylonica* contributed only a few individuals and this species is commonly found in the intertidal areas (Ghatpande et al., 2024). Although storms did not directly affect the organisms during sampling, the disaster event could alter the surrounding area by changing wave height (Corte et al., 2017). The occurrence of *A. ceylonica* in coral reef ecosystems is likely due to strong-storm generated waves which may have drifted away the gastropods and led them to inhabit new habitats (Basir et al., 2022).

In Table 4.14 and Table 4.16, the diversity of coral reef gastropods in Pulau Yu Besar and Pulau Yu Kecil represents a low category with *H'* values < 2.0. The low diversity of gastropods could be attributed to their patchy distribution pattern within coral reefs as some gastropods were difficult to locate in each coral colony along the transect (Bachok et al., 2021). Additionally, the limited spatial scales of the islands reduce habitat heterogeneity, which is necessary for supporting greater species diversity and increase the possibility of encountering the same dominant species across the islands (Chase et al., 2019; Loke et al., 2022). However, the higher species richness and evenness of gastropods could be explained by the presence of branches of coral in both islands as a shelter for them (Stella et al., 2022). Despite low species diversity, localized habitat conditions significantly influenced community composition and abundance as the complex reef structure provided more microhabitats for them, thereby promoting greater species coexistence (Tsafack et al., 2019). Therefore, the findings from Pulau Yu Besar and Pulau Yu Kecil demonstrate that factors such as live coral cover, reef complexity and exposure to environmental stressors such as wave energy strongly influence the coral reef gastropods community (Seinor, 2020; Barrientos-Luján et al., 2021; Kamerman, 2023).

5.5 Shell metric and biomass among islands

From the result of Table 4.17, the length of gastropod individuals in the study areas was measured, yielding mean values for shell length, dry weight and condition index. Shell length was used to determine the growth and age structure of the gastropod community. A positive correlation between shell length and width indicates isometric growth for gastropods, whereby the shell width increases proportionally with shell length (Allsay & Dwi, 2023). According to Saponari et al. (2021), gastropod age was categorised based on shell lengths; recruit (<10 mm), juvenile (10-20 mm) and adult (>20 mm). Although the mean shell length of *DRG* and *AMG* in all sampling stations indicated that the snail population was mainly composed of adults, both species at PTG recorded longer shell lengths than those at other Terengganu marine protected islands with mean values of 31.55 ± 3.27 mm and 29.87 ± 5.34 mm, respectively. In conditions of limited resources such as reduced coral cover for food and shelter following the Pabuk storm event, the gastropod aggregations may lead to an intraspecific competition where size-dependent density favours better competitors (Saponari et al., 2021). This could significantly affect population structure. Thus, *DRG* and *AMG* adults in PTG may be considered superior competitors, dominating resources and potentially causing juvenile mortality more than in other islands.

In addition, *MRS* and *DCR* were observed at nearly all sampling stations except in PRD, PKS, PTG and PYB. Meanwhile, *ACY* was only found in PYB and PYK. When comparing species, the shell length of *MRS* and *ACY* from PYK and *DCR* from PBD were the longest with values of 25.17 ± 2.96 mm, 74.39 mm and 40.72 ± 2.33 mm, respectively. According to Haumahu et al. (2020), the growth of an organism can be measured by increments in length and weight. They also stated that the growth of organisms can be measured through length frequency distribution to estimate their age cohorts. In addition, the shell length dimensions are influenced by the condition of the substrate in the waters (Tebiary et al., 2022). Therefore, the overall coral cover in PYK and PBD could be considered in ‘fair’ condition, although the Pabuk storm had impacted the east coast islands in Terengganu. However, Tebiary et al. (2022) also mentioned that water conditions with high pollution levels can still lead to a reduction in shell size. Consequently, environmental factors including the movement of water currents are known to reduce the body size of gastropods due to the absence of protected areas.

Dry weight is a representative measure for estimating the total biomass of mollusc population. The highest dry weight for each species was observed with *DRG*=4.97 ± 1.76 g, *AMG*=2.19 ± 0.49 g, *MRS*=2.74 0.91 g, *DCR*=13.84 ± 4.23 g and *ACY*=61.85 g, respectively. The biomass of gastropods in waters is influenced by biotic and abiotic environments as well as the gastropod's tolerance to environmental factors (Fadliyah et al., 2021). Gastropod biomass may be higher when organic matter is available during the sampling period. This is likely due to surface runoff and drainage that occurred before sampling, introducing a significant amount of organic matter and nutrients, which in turn supported the proliferation of benthos biomass including gastropods (Dhivaharan, 2021). The condition index (*CI*) is used to measure the ecophysiological aspects, summarising physiological activity such as growth, reproduction and mortality under given environmental conditions (Baharuddin et al., 2017). The *CI* remained steady for the gastropod species, suggesting that *DRG, AMG, MRS, DCR* and *ACY* were under the ‘thin’ category of fatness. This may be due to their gonads being in a resting state or undergoing the gametogenesis phase (Baharuddin et al., 2017).

Compared to *ARD, CCL* and *CVL, CCR* exhibited a longer shell length. This is probably due to its high-spired shells, which offers better protection from rough wave conditions. The dry weight of *CCR* was also the highest among these species at 10.28 g, possibly due to the abundance of preferred food for cerithiid gastropods in PTG. However, *CCR* had the lowest condition index with 1.04. According to Lah et al. (2019), the condition index can be used to monitor the maturation or spawning development of molluscs. The *CI* values tend to decline during the spawning season as reproductive activities are biologically demanding and require a significant amount of energy. Molluscs typically store energy in the form of lipids before spawning to be used during spawning activity. These lipids play a crucial role in gonadal tissue maturation. As a result, lipid levels are notably higher in gonads or storage tissues before spawning but decline after the spawning season (Lah et al., 2019).

5.6 Shell metric and biomass within islands

When comparing shell metrics and biomass of gastropods at coral reefs in Pulau Bidong, *DRG* from PPK recorded the highest values for shell length, dry weight and condition index, despite having fewer individuals than PPC (Table 4.18). This pattern is probably due to the coral reef at PPK providing a more sheltered environment, which may allow the gastropods to grow larger due to less disturbances (Seinor et al., 2020). In addition, the higher dry weight and condition index of individuals from PPK could reflect a sufficient nutrient supply in their food before the sampling period. Similarly, the longer shell length, heavier dry weight and higher condition index of *DCR* in DLT could be attributed to the effects of Pabuk storm, which severely damaged coral and left exposed coral tissue (Safuan et al., 2020). Therefore, this condition may have allowed *DCR* to assess food resources more efficiently.

Based on the results in Table 4.19, the shell length, dry weight and condition index of coral reef gastropods in Pulau Kapas were assessed. Despite having the fewest individuals among *DRG* and *AMG*, both species from TJ exhibited the longest shell length and heaviest dry weight. The depletion of coral reefs in Pulau Kapas may have contributed to the declining number of gastropods (Hong et al., 2020). This decline could reduce intraspecific competition among *DRG* and *AMG* in TJ as such competition actually can lead to uneven resource partitioning. Uneven resource partitioning can reduce the reproduction, survival and growth rate (Uchmański et al., 2018). Consequently, the absence of conspecifics reduces competition for limited food and space, allowing gastropods to allocate available resources more efficiently towards growth and biomass. The condition index of *DRG* in Pulau Kapas remained steady as their gonads were at rest or poorly developed (Fernández et al., 2016). In contrast, the condition index of *AMG* was higher in BT due to optimal environmental conditions such as favourable temperature, salinity and better food availability compared to the other study sites (Collin & Ochoa, 2016). The higher shell length of *MRS* in TJ (>20 mm) suggests that most individuals were adults (Saponari et al., 2021). However, their dry weight was low possibily due to unfavourable conditions such as low nutritional resources (Dhivaharan, 2021), while the low condition index may be attributed to spawning activities (Bahtiar et al., 2023).

Table 4.20 showed that *DRG* in Pulau Perhentian exhibited differences in shell length and dry weight, while no significant difference was observed in condition index. Among 11 sampling sites in Pulau Perhentian, *DRG* from DLG recorded the highest shell length, followed by TPH. Although DLG and TPH did not have the highest number of gastropods, the lower availability of preferred food resources such as *Acropora* spp. may have triggered intraspecific competition (Zhang et al., 2024). According to Zainuddin et al. (2024), the dominance of adult individuals over limited preferred coral may lead to increased mortality of juveniles and intermediates. Therefore, the presence of only adult individuals in DLG and TPH could explain the higher shell length. The heaviest dry weight of *DRG* was recorded in SBL and DLG. This observation may be linked to the dominance of adults for *DRG* as adults generally exhibited higher metabolic rates that contribute to greater dry weight (Cozzoli et al., 2020). The *CI* values of *DRG* across Pulau Perhentian sampling sites were relatively consistent, suggesting that the gastropods were well-adapted to environmental fluctuations and not under stress (Baharuddin et al., 2017). Similarly, the shell length, dry weight and condition index of *AMG* were relatively constant, considering the species' ability to adapt to various microhabitats. Its slender shell shape also helps in survival under harsh environmental conditions (Baharuddin et al., 2018). Higher shell metric and biomass values for *DCR* and *MRS* were still observed in PSB due to the 'fair' condition of coral reefs that support their growth (Lei et al., 2022). Although only a single individual of *CCL* was found in Pulau Perhentian, it was classified as an adult, indicating that the species can adapt to environmental conditions in PR1.

In Pulau Redang, species such as *ARD* notably exhibited the highest values of shell length and dry weight (Table 4.21). The cone-shaped shell of this species is considered an adaptation that enhances their survival in adverse environments, including intense winds generated by the Tropical Pabuk Storm (Zainuddin et al., 2024). The higher dry weight and condition index of *ARD* reflect good health, and their reproductive cycle was supported by abundant nutritional resources (Li et al., 2011). Compared to *DRG* from TK and KB, individuals from PL displayed the longest shell length and heaviest dry weight. Although TK had the highest percentage of *Acropora* corals, Lee et al. (2020) reported that the coral species in PL were the healthiest with new coral colonies actively growing in that area. This suggests that healthier corals in PL supported better growth and biomass accumulation in gastropods. However, the steady *CI* of *DRG* across all study sites indicates that stable water quality and salinity may positively influence the ecophysiological condition of gastropods (Marsden & Baharuddin, 2015). The abundance of branching corals in KB may have contributed to the high value of shell length and dry weight as these corals provide shelter from predators, suitable living space and increased food availability for gastropods (Hong et al., 2020). The highest condition index of *MRS* in KB is likely due to less competition from conspecifics. This reduced competition may have allowed greater access to nutrients, thereby supporting gonadal development and sexual maturation in gastropods (Mérot & Collins, 2012).

From Table 4.22, *DRG* and *DCR* from RJ and TP recorded the highest shell length values compared to individuals in SN and LW. According to a survey by Hong et al. (2020) on coral reefs in Pulau Tenggol, the highest percentage of live coral cover was observed in RJ, while the coral reefs in TP were classified as being in 'fair' condition. These conditions provide an ideal environment for gastropods to live comfortably and support their growth. The higher dry weight and condition index of *DRG* and *DCR* in TP could also be attributed to reef conditions. Although Hong et al. (2020) stated the coral condition in TP as 'fair', a survey conducted by Reef Check Malaysia (2020) earlier in same year reported that coral reefs in TP were in 'good' condition. Given the close timing of these surveys, gastropods may have already assessed to good food quality during the sampling period. The shell length and dry weight of *CVL* in TR were higher than in LW. The good health of *Porites* corals in TR likely contributed to higher-quality reef tissue content as Hong et al. (2020) reported that the island experiences minimal disturbances and low human activities, resulting in a higher percentage of coral cover. However, the condition index of *CVL* in LW was higher than TR, possibly due to gonads or storage tissues of gastropods being in a mature and well-developed stage (Lah et al., 2019). The shell length, dry weight and condition index of *AMG* in LW were also relatively high. This may be due to the species' slender shell shape that allows them to survive in harsh environments and navigate more tight spaces, thereby improving their ability to find abundant food resources for development (Baharuddin et al., 2018). The shell metric and biomass of *CCR* in SN were considered high, suggesting that the gastropods were not experiencing stress.

Table 4.23 showed the shell metrics and biomass of gastropods inhabiting the coral reefs in Pulau Yu Besar. The highest values of shell length, dry weight and condition index of *DCR* were still observed in S2. Interestingly, although S2 had the highest percentage of coral mortality caused by the Pabuk storm event, it is possible that *DCR* developed their size and biomass when corals were still abundant before the disturbances. This conclusion supported by Bachok et al. (2021). who documented the coral percentage in Pulau Yu Besar one year after the natural event. No significant differences in shell length suggested that *DRG* in S1 and S2 may belong to similar sub-populations, resulting in comparable shell length. The constant dry weight and condition index of *DRG* also indicate that the population of this species was not under stress (Baharuddin et al., 2017). *AMG* and *ACY* in S1 exhibited the longest shell length, heaviest dry weight and condition index as S1 had the most abundant and healthiest coral reefs. These conditions provided better food availability and fostered the gastropod's growth and development (Haumahu et al., 2020; Baharuddin et al., 2019).

Lastly, *DCR* and *MRS* from S1 exhibited the highest values for shell length, dry weight and condition index compared to the individuals from S2 and S3 in Pulau Yu Kecil (Table 4.24). Although S1 had the lowest percentage of live coral than S2 and S3, the low sedimentation levels in Pulau Yu Kecil might significantly impact on shell metrics and biomass (Reef Check Malaysia, 2020). According to Risk and Edinger (2011), sedimentation can reduce species richness, hinder coral growth rate and lead to partial or complete mortality in the coral ecosystem. Therefore, the low sedimentation levels in Pulau Yu Kecil contributed significantly to the enhancement of shell metrics and biomass. The considerably higher shell length, dry weight, and condition index for *DRG, ACY*, and *AMG* in Pulau Yu Kecil may also be attributed to the island’s better live coral cover than Pulau Yu Besar, supporting the growth and survival of gastropods (Reef Check Malaysia, 2020).

5.7 Feeding guilds of coral reef gastropods

Percentage of feeding guilds among islands

In Terengganu marine protected islands, three types of feeding guilds were identified for coral reef gastropod communities: corallivorous, carnivorous and herbivorous (Figure 4.23). For the corallivorous category, PPH reported the highest percentage with 28.40%, compared to other islands (Figure 4.23). Apart from *Porites* dominated the island, PPH contributed a significant number of corallivores as the island has covered more than 10 sites compared to other islands. Consequently, the higher number of sampling sites may contribute to a higher number of gastropods, particularly corallivores. However, a larger aggregation of corallivorous gastropods may negatively affect coral health, resulting in a decline of live coral cover (Gautrand et al., 2023). Based on Figure 4.23, PPH and PRD recorded 35.14% and 29.73% as both islands had a higher number of carnivorous gastropods with 65 and 55 individuals. The presence of carnivorous gastropods may also serve as a form of biological control by preying on juvenile *Drupella* individuals (Ruan, 2021). The herbivorous gastropods were only observed in PRD, PPH and PTG (Figure 4.23). The higher presence of herbivorous gastropods in PRD compared to the other islands is due to the higher algae coverage dominating the coral surfaces. A study conducted in the Caribbean by Henry et al. (2019) demonstrated that herbivorous gastropods can enhance sexual propagation efficiency of *Acropora cervicornis* by slightly reducing algae growth on coral and promoting coral resilience. Therefore, a higher presence of algae grazers may have facilitate the removal of turf algae with minimal physical damage to coral recruits. Although herbivorous snails alone may not effectively control algae growth in natural systems, however native herbivores such as *Diadema antillarum* could eventually be propagated into more holistic coral reef restoration efforts (Henry et al., 2019).

Percentage of feeding guilds within islands

The percentage of feeding guilds for gastropods such as corallivores was the highest on each island (Figure 4.24). PPH and PRD contributed to the highest percentage of corallivores with 20.45%. and 15.91%, respectively. In recent years, corallivores have increasingly threatened the coral reefs with aggregations of ectoparasitic gastropods such as *Drupella* spp. becoming the significant obstacles to conservation efforts to protect degraded coral ecosystems (Lei et al., 2022). The prey preferences of *Drupella* gastropods vary in sampling sites according to the abundance and availability of coral prey. In this study, the possibility of a high occurrence of corallivorous gastropods is due to the presence of the family Acroporidae known as meaty and nutrition-packed coral for these gastropods (Lei et al., 2022). The coral reef gastropods will also be more abundant in stations with relatively high coral cover than in stations with low coral coverage. This finding was consistent with the theory of optimal foraging, which assumed that predators fed in such a way as to trade-off between the alternative available coral prey abundances (Cumming, 2009).

The percentage of carnivorous gastropods was higher in PPH and PRD, with 9.23% and 7.81%. Most carnivorous gastropods found on both islands were from the Muricidae family. According to de Carvalho-Souza and González-Ortegón (2022), Muricidae is one of the prominent family for carnivorous snails that utilize a specialized shell-drilling ability to assess their prey. The highest presence of carnivorous gastropods in PPH to feed on small molluscs such as corallivorous juveniles could be used as a biological control. This is because some organisms can act as predators or competitors of *Drupella* snails, helping to control their population (Zhang et al., 2024). In addition, the presence of herbivorous gastropods could be recorded in PPH, PRD and PTG. PRD had a higher percentage of this feeding guild of gastropods than other stations. Apart from a relatively higher algae coverage in PRD, the presence of algae-grazing gastropods such as *A. rhodostomum* in PRD could also be supported by the distribution behaviour of this species. As Sanpanich and Duangdee (2018) stated that the turbinid gastropod species was commonly found around coral reef ecosystems. This evidence could be supported by the researchers' observation that *A. rhodostomum* was the third most widespread molluscan found in coral areas of the Mergui Archipelago after pearl oysters and muricid gastropods.

5.8 Management and strategies to address corallivorous gastropods, *Drupella* spp.

The selective and adaptable feeding habits of coral predators such as *Drupella* spp. exert a significant impact on the coral ecosystem, leading to shifts in coral communities. During initial outbreaks of corallivorous gastropods, the researchers observed that *Drupella* exhibited a strong preference for branching corals over massive forms (Saponari et al., 2021). This selective predation contributed to alterations in coral compositions and diversity (Lachs et al., 2019). Therefore, controlling corallivorous gastropods and mitigating their impacts on the coral reefs requires a comprehensive approach. Effective management strategies are essential to minimize the risk of outbreaks and protect coral ecosystems.

The strategies should aim to enhance coral reef health by reducing human activities. Reducing anthropogenic impacts and improving coral reef health is imperative to mitigate future outbreaks of corallivorous gastropods and sustain the resilience of coral communities (Zhang et al., 2024). For example, research on the Great Barrier Reef has shown that improving water quality through the reduction of activities such as agricultural runoff can decrease the macroalgae cover and increase the richness of hard corals (Déath & Fabricius, 2010). Terengganu Marine Park (TMP) islands such as Pulau Perhentian, Pulau Redang, Pulau Kapas, Pulau Tenggol, Pulau Yu Besar and Pulau Yu Kecil boast rich coral reef ecosystems but face challenges from local disturbances that significantly affect reef health (Akmal et al., 2019; Safuan et al., 2021). Establishing marine protected areas (MPAs) is crucial for marine conservation as they benefit both coastal communities and coral reef ecosystems by preserving essential ecosystem functions (Graham et al., 2011). However, Safuan et al. (2021) stated that non-TMP islands such as Pulau Bidong boast healthier reefs than TMP islands like Pulau Perhentian. Furthermore, the Department of Marine Park 2016 reported a rising trend in tourist arrivals to Pulau Perhentian, increasing from 123,159 in 2005 to 244,762 in 2015. This surge in tourism has led to the development of various infrastructures on the island (Nasir et al., 2017). Rees (1992) and Islam et al. (2013) emphasised that the development in marine park areas should be strictly controlled to prevent degradation of coral reefs. Therefore, the local government is responsible for enforcing regulations and managing tourism-related infrastructures by limiting tourism activities on TMP islands (Safuan et al., 2022). In addition, protecting coral reef fishes, particularly herbivorous can efficiently control macroalgae growth on coral surfaces, thereby enhancing coral resilience to corallivore predation (Kamalakannan et al., 2014; Sheppard et al., 2023).

Biological control methods offer another strategy to manage coral predators, whereby certain organisms act as natural predators to corallivores. For example, the coral guard crabs (*Trapezia* spp.) which are commonly found inhabiting *Acropora* corals exhibited territorial behaviour against *Drupella rugosa* with *Trapezia cymodoce* reducing *D. rugosa* feeding rates by 22.9% (Samsuri et al., 2018). However, the other crustaceans such as *Alpheus lottini* and *Cymo andreossyi* were more effective coral defenders due to their larger pincers that can crush *Drupella* shells. The giant triton snail (*Charonia tritonis*) is a predator of harmful corallivorous organisms such as crown-of-thorns starfish (CoTS) (Bose et al., 2017; Ratianingsih et al., 2017). The Australian government has allocated $568,000 to study the reproductive biology of giant triton snails, leading to the successful breeding of 100,000 juveniles intended for use in the biological control of harmful corallivores, including gastropods (Chadwick, 2017). Nonetheless, biological control must be approached cautiously with thorough assessment to prevent potential ecological disasters in coral reef ecosystems.

Manual removal is another management method for controlling corallivorous gastropods. This includes the removal of both adult and juvenile individuals (Zhang et al., 2024). It is also recommended to inspect exposed coral skeletons to detect and eliminate *Drupella* egg capsules, thereby reducing the potential of population outbreaks. Sam et al. (2017) reported that a single female *Drupella rugosa* can deposit an average of 52 egg capsules, each containing 67 embryos. This ectoparasitic gastropod could produce 3484 embryos per spawning event. In Japan, the scientists implemented an extermination program targeting corallivorous gastropods before the spawning season (Kitamura et al., 2022). As a result, Japan successfully maintained a high density of *Acropora* population despite being more susceptible to cold temperatures (Zhang et al., 2024). In Thailand, volunteer divers manually removed 14000 *Drupella* individuals, reducing their density from 7.9 ind/m2 in 2010 to 5.6 ind/m2 in 2011 (Scott et al., 2017). However, manual removal only provides temporary relief from the destruction caused by corallivorous gastropods. This approach cannot solve the issue fundamentally as it is costly and limited by operational depth, making it impractical to remove gastropods in deeper waters (Zhang et al., 2024).

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The checklist of gastropods found within coral areas in Terengganu of Peninsular Malaysia is still in an inchoate state. Many marine protected islands in this state are underexplored for their gastropod diversity. To date, this study has contributed to discovering important information on gastropods inhabiting corals in Terengganu marine protected islands by assessing species diversity, shell metrics, biomass and feeding guilds of gastropods. Overall, the diversity of coral reef gastropods was low with Shannon-Wiener index values below 1.5. The identified gastropod comprises several species such as *A. rhodostomum*, *C. coralium*, *C. columna*, *C. violacea*, *D. cornus*, *D. rugosa*, *M. spinosa*, *A. ceylonica* and *A. marginalba*. *Drupella rugosa* was the most abundant gastropod to be found. Shell metric and biomass values varied between the islands. Notably, the majority of coral reef gastropods were classified as corallivores, highlighting their potential ecological impacts on coral communities.

This study also emphasizes that shell characteristics through length measurement is a very interesting research topic that needs to be highlighted in the ecological research of coral-associated gastropods in Terengganu, Peninsular Malaysia. Some factors including natural and anthropogenic disturbances can influence the dynamics of coral ecosystems in marine protected islands. Investigating this topic can provide insight into how gastropods inhabited corals respond to these factors. In addition, the knowledge of feeding guilds also provides essential information on coral reef gastropods to attain a profound understanding of the roles of this malacofauna especially corallivorous during the phases of coral mortality and recovery in Terengganu marine protected islands.

Such data and information aid local authorities such as the DoFM and stakeholders in improving conservation strategies for marine protected areas by ensuring sustainable management of coral reefs to reduce outbreaks of corallivores. This research also encourages local communities in Terengganu, especially fishermen and tourism operators to engage in sustainable practices that minimize damage to coral reef ecosystems.

For future research, nighttime sampling is strongly recommended as gastropods are nocturnal and more active at night. This approach may yield more comprehensive insight into their diversity and behaviour. In addition, future research should explore ecological aspects such as niche aggregations, interspecific and intraspecific competition, and microhabitat preferences. These investigations would help to clarify the ecological roles and spatial distribution of coral reef gastropods in Terengganu marine protected islands. Lastly, environmental parameters focusing on ocean acidification such as pH, Dissolved Inorganic Carbon (DIC) and partial pressure of carbon dioxide (pCO_2) should be taken in the future to correlate the relationship between species occurrence and distribution. Long-term monitoring on coral-gastropod interactions under controlled and natural conditions could enhance the knowledge base and improve conservation initiatives.

REFERENCES

Abbott, R. T., and Dance, S. P. (2000). Compendium of Seashells: A Full-Colour Guide to More Than 4,200 of the World's Marine Shells. (pp. 1 – 393). Odyssey Publishing, California, Western United States.

Adhavan, D., Prakash, S., and Kumar, A. (2021). Tube Dwelling Gastropod an Indicator of Coral Reef Status at the Tropical Reef of Palk Bay Region, Southeast Coast of India. Indian Journal of Geo Marine Sciences, 50(7): 585 – 587.

Akmal, K. F., Shahbudin, S., Faiz, M. H. M., and Hamizan, Y. M. (2019). Diversity and Abundance of Scleractinian Corals in the East Coast of Peninsular Malaysia: A Case Study of Redang and Tioman Islands. Ocean Science Journal, 54(3): 435 – 456.

Albano, P. G., Steger, J., Bošnjak, M., Dunne, B., Guifarro, Z., Turapova, E., and Zuschin, M. (2021). Native Biodiversity Collapse in the Eastern Mediterranean. Proceedings of the Royal Society B, 288(1942): 1 – 9.

Alemu, J. B., Ishmael-Lalla, M., Mannette, R. P., Williams, G. J., and Agard, J. (2021). Hydro-Morphological Characteristics Provide Insights into Coral Reef Ecosystem Services and Disservices. Ecosystem Services, 49: 1 – 10.

Allsay, K. A. C., and Dwi, E. D. S. (2023). Shell Morphology and Size Distribution of *Turbo* spp in Sepanjang Beach by Shell Collecting: An Initial Survey. BIO Web of Conferences, 70: 1 – 10.

Anandhi, G. (2025). In Terengganu, the Coast is Clear and Inviting. Retrieved from http://dac.umt.edu.my:8080/xmlui/handle/123456789/16525.

Apprill, A., Girdhar, Y., Mooney, T. A., Hansel, C. M., Long, M. H., Liu, Y., Zhang, G. W., Kapit, J., Hughen, K., Coogan, J., and Greene, A. (2023). Toward a New Era of Coral Reef Monitoring. Environmental Science and Technology, 57(13): 5117 – 5124.

Averbuj, A., Büchner-Miranda, J. A., Salas-Yanquin, L. P., Navarro, J. M., Pardo, L. M., Matos, A. S., Pechenik J. A., and Chaparro, O. R. (2021). Energetic Trade-Offs: Implications for Selection Between Two Bivalve Prey Species by a Carnivorous Muricid Gastropod. Plos One, 16(4): 1– 21.

Awang, U. N., Jasni, N. A., Sahari, M. S., Nor, S. M., Baharuddin, N., Deraman, M.

Y., and Omar, W. B. (2022). Abundance of Marine Gastropods (Mollusca: Gastropoda) in Replanted Mangrove Forests Along Kerteh River, Terengganu, Malaysia. AACL Bioflux, 15(6): 3250 – 3257.

Ayal, Y., and Safriel, U. N. (1982). Role of Competition and Predation in Determining Habitat Occupancy of Cerithiidae (Gastropoda: Prosobranchia) on the Rocky, Intertidal, Red Sea coasts of Sinai. Marine Biology, 70(3): 305 – 316.

Azman, N. M., Sah, S. A. M., Ahmad, A., and Rosely, N. F. (2019). Contribution of Rice Fields to Bird Diversity in Peninsular Malaysia. Sains Malaysiana, 48(9): 1811– 1821.

Azmi, M. I. M. (2014). Valuing the Potential Economic Value of Mangrove Resources in Setiu Wetlands, Terengganu, Malaysia: A Preliminary Findings. International Journal of Education and Research, 2: 487 – 504.

Bachok, Z., Hong, T. C., Jaafar, S. N., Chee, P. S., Idris, I., Baharuddin, N., and Borkhanuddin, M. H. (2021). Pulau Kapas and Pulau Yu: Baseline Data on Research Site. (pp. 1–28). Annual Report 2021.

Baharuddin, N., Idris, I., and Zulkifli, S. Z. (2017). Population Structure Using Shell Morphometric and Carbonate Growth of Corallivorous Gastropods *Drupella rugosa* in Pulau Redang. (pp. 120 – 126). Conference Paper.

Baharuddin, N., Martin, M. B., Nagappan, T., and Borkhanuddin, M. H. (2017). Checklist of Mangrove Snails (Mollusca: Gastropoda) in Setiu Wetlands. (pp. 1 – 9). World Wildlife Fund, Setiu, Malaysia.

Baharuddin, N., Basri, N. B., and Syawal, N. H. (2018). Marine Gastropods (Gastropoda; Mollusca) Diversity and Distribution on Intertidal Rocky Shores of Terengganu, Peninsular Malaysia. AACL Bioflux, 11(4): 1144 – 1154.

Baharuddin, N., and 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.

Baharuddin, N., Basir, N. H. M., and Zainuddin, S. N. H. (2019). Tropical Intertidal Gastropods: Insights on Diversity, Abundance, Distribution and Shell Morphometrics of Pulau Bidong, Malaysia. AACL Bioflux, 12(4): 1375 – 1387.

Baharuddin, N., Fahmi, A. D. M., Zainuddin, S. N. H. and Idris, I. (2020). Corallivores Gastropod, *Drupella* spp. Prevalence in Pulau Redang. (pp. 36 – 43). Post COVID-19 Marine Life Status at Marine Parks Islands of Terengganu Report.

Bahtiar, B., Fekri, L., Ishak, E., Purnama, M. F., Permatahati, Y. I., and Nur, I. (2023). Temporal Variations in Growth and Condition Index of Kalandue Clams (*Polymesoda erosa*, Solander 1786) in Kendari Bay, Southeast Sulawesi. IOP Conference Series: Earth and Environmental Science, 1224: 1 – 10.

Bai, Y., Hu, R., Wang, L., and Li, D. (2024). Reduce Pollution, Establish Protected Areas, Manage Fisheries Properly? How to Protect Coral Reefs Based on Carbon Trading. Frontiers in Marine Science, 11: 1 – 17.

Bara'langi, L. N. T., Tuwo, A., Yusuf, S., Husain, A. A. A., and Tresnati, J. (2021). Zooxanthellae Density in Different Zone and Life Form in Inner and Outer Zone of Spermonde Islands. Jurnal Ilmu Kelautan SPERMONDE, 7(1): 27 – 35.

Barbosa, F. D., Lúcia Dias, T., de Faria Lopes, S., Cristina de Souza Duarte, R., and Maria Duarte do Amaral, F. (2019). Community Structure and Functional Traits of Mollusks Associated with Coastal Reef Macroalgae in Northeastern Brazil. Marine Ecology, 40(5): 1 – 13.

Barco, A., Claremont, M., Reid, D. G., Houart, R., Bouchet, P., Williams, S. T., Cruaud, C., Couloux, A., and Oliverio, M. (2010). A Molecular Phylogenetic Framework for the Muricidae, a Diverse Family of Carnivorous Gastropods. Molecular Phylogenetics and Evolution, 56(3): 1025 – 1039.

Barnes, R. S. K. (2003). Interactions Between Benthic Molluscs in a Sulawesi Mangal, Indonesia: The Cerithiid Mud-Creeper *Cerithium coralium* and Potamidid Mud-Whelks, *Terebralia* spp. Journal of the Marine Biological Association of the United Kingdom, 83(3): 483 – 487.

Barrientos-Luján, N. A., López-Pérez, A., Ríos-Jara, E., Ahumada-Sempoal, M. Á., Ortiz, M., and Rodríguez-Zaragoza, F. A. (2017). Ecological and Functional Diversity of Gastropods Associated with Hermatypic Corals of the Mexican Tropical Pacific. Marine Biodiversity, 49(1): 193 – 205.

Barrientos-Luján, N. A., Rodríguez-Zaragoza, F. A., and López-Pérez, A. (2021). Richness, Abundance and Spatial Heterogeneity of Gastropods and Bivalves in Coral Ecosystems Across the Mexican Tropical Pacific. Journal of Molluscan Studies, 87(2).

Barroso, C. X., Lotufo, T. M. D. C., Matos, A. S., Carneiro, P. B. D. M., and Matthews-Cascon, H. (2022). The Distribution of Marine Gastropods is More Influenced by Larval Development Than by Adult Characteristics. Marine Biology, 169(6): 1 – 10.

Barton, J. A., Bourne, D. G., Humphrey, C., and Hutson, K. S. (2020). Parasites and

Coral-Associated Invertebrates that Impact Coral Health. Reviews in Aquaculture, 12(4): 2284 – 2303.

Basir, N. H. M., Baharuddin, N., and Ahmad, A. (2022). Impact of Tropical Storm Pabuk on Intertidal Gastropods in Bidong Island, Malaysia. (pp. 119 – 128). Springer Nature Switzerland, Switzerland.

Beeden, R., Maynard, J., Puotinen, M., Marshall, P., Dryden, J., Goldberg, J., and Williams, G. (2015). Impacts and Recovery from Severe Tropical Cyclone Yasi on the Great Barrier Reef. Plos One, 10(4).

Benítez, S., Lagos, N. A., Griesshaber, E., López, J., Villanueva, P. A., Moscoso, F., and Navarro, J. M. (2022). Influence of Kelps Nutritional Quality on Physiological Traits of the Marine Snail *Tegula atra* (Trochoidea). Marine Biology, 169(9): 1 – 9.

Bessey, C., Babcock, R. C., Thomson, D. P., and Haywood, M. D. E. (2018). Outbreak Densities of the Coral Predator *Drupella* in Relation to in situ *Acropora* Growth Rates on Ningaloo Reef, Western Australia. Coral Reefs, 37(4): 985 – 993.

Bieg, C., Vallès, H., Tewfik, A., Lapointe, B. E., and McCann, K. S. (2024). Toward a Multi-Stressor Theory for Coral Reefs in a Changing World. Ecosystems, 27(2): 310 – 328.

Bouchet, P., Lozouet, P., Maestrati, P., and Heros, V. (2002). Assessing the Magnitude of Species Richness in Tropical Marine Environments: Exceptionally High Numbers of Molluscs at a New Caledonia Site. Biological Journal of the Linnean Society, 75(4): 421– 436.

Bose, U., Wang, T., Zhao, M., Motti, C. A., Hall, M. R., and Cummins, S. F. (2017). Multiomics Analysis of the Giant Triton Snail Salivary Gland, a Crown-of-Thorns Starfish Predator. Scientific Reports, 7(1): 1 – 14.

Brandt, M. E., Olinger, L. K., Chaves-Fonnegra, A., Olson, J. B., and Gochfeld, D. J. (2019). Coral Recruitment is Impacted by the Presence of a Sponge Community. Marine Biology, 166(4): 1 – 13.

Brathwaite, A., Clua, E., Roach, R., and Pascal, N. (2022). Coral Reef Restoration for Coastal Protection: Crafting Technical and Financial Solutions. Journal of Environmental Management, 310: 1 – 14.

Bravo, H., Xu, T., and van der Meij, S. E. (2021). Conservation of Coral-Associated Fauna: The Encyclopedia of Conservation. (pp. 1 – 8). Earth Systems and

Environmental Sciences. Elsevier, Groningen, Netherlands.

Bravo, H., Dromard, C. R., van der Meer, M. T., Schleimer, A., and van der Meij, S. E. (2024). Dining on Corals: Stable Isotope Evidence for Close Trophic Connection Between Gall Crabs (Cryptochiridae) and Their Stony Coral Hosts. Symbiosis, 92(1): 51 – 62.

Briggs, A. A., and Carpenter, R. C. (2019). Contrasting Responses of Photosynthesis and Photochemical Efficiency to Ocean Acidification under Different Light Environments in a Calcifying Alga. Scientific Reports, 9(1): 1 – 10.

Bruckner, A. W., Coward, G., Bimson, K., and Rattanawongwan, T. (2017). Predation by Feeding Aggregations of *Drupella* spp. Inhibits the Recovery of Reefs Damaged by a Mass Bleaching Event. Coral Reefs, 36(4): 1181 – 1187.

Bruton, J., Baird, D., and Coetzee, P. S. (1991). Population Structure and Yield-Per-Recruit Analysis of the Giant Periwinkle *Turbo sarmaticus* in the Cape St Francis Region, South Africa. South African Journal of Marine Science, 11(1): 345 – 356.

Burns, J. H. R., Fukunaga, A., Pascoe, K. H., Runyan, A., Craig, B. K., Talbot, J., Pugh, A., and Kosaki, R. K. (2019). 3D Habitat Complexity of Coral Reefs in the Northwestern Hawaiian Islands is Driven by Coral Assemblage Structure. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42: 61 – 67.

Burns, N. M., Bailey, D. M., and Hopkins, C. R (2025). Assessing the Implications of Wrasse Fishing for Marine Sites and Features. (pp. 1–62). NatureScot Commission Report No. RR1207.

Cumming, R. L. (2009). Case Study: Impact of *Drupella* spp. on Reef-Building Corals of the Great Barrier Reef. (pp. 1– 44). Report to the Great Barrier Reef Marine Park Authority.

Cahyadi, G. A. B. Y. P., Pinasti, R., Salwa, A., Devi, M. A., Fajriana, L. R., Qudsiyati, N., Calista, P., and Eprilurahman, R. (2021). Biodiversity of Gastropods in Intertidal Zone of Krakal Beach, Gunungkidul, Yogyakarta. Nusantara Science and Technology Proceedings, 2021: 16 – 24.

Canteri, B. (2024). Investigating Climate Change and Nutrient Pollution Effects on *Drupella rugosa* Coral Reef Destruction in Koh-Tao, Thailand. The Plymouth Student Scientist, 17(2): 1 – 21.

Carpenter, K. E., and Niem, V. H. (1998). FAO Species Identification Guide for

Fisheries Purposes. (pp. 1 – 686). Food and Agriculture Organization, Rome, Italy.

Castejón, D., García, L., and Andrade, C. A. (2023). Crustose Coralline Algal Factors Determining the Success of Limpet (Patellogastropoda: Patellidae) Settlement: Species, Exposure Time, Area and Soluble Cues. Marine Biology, 170(12): 1 – 21.

Ceccarelli, D. M., Lestari, A. P., and White, A. T. (2022). Emerging Marine Protected Areas of Eastern Indonesia: Coral Reef Trends and Priorities for Management. Marine Policy, 141: 1 – 15.

Chadwick, E. (2017). Giant Sea Snails Join the Fight to Save the Reef. Retrieved from https://www.aims.gov.au/information-centre/news-and-stories/giant-seasnails-join-fight-save-reef.

Chaijaroen, P. (2022). Coral Reef Deterioration and Livelihoods of Coastal Communities: An Economics Perspective: Corals-Habitat Formers in the Anthropocene (pp. 1 – 16). IntechOpen, United Kingdom.

Chase, J. M., McGill, B. J., Thompson, P. L., Antão, L. H., Bates, A. E., Blowes, S. A., Dornelas, M., Gonzalez, A., Magurran, A. E., Supp, S. R., Winter, M., Bjorkman, A. D., Bruelheide, H., Byrnes, J. E. K., Cabral, J. S., Elahi, R., Gomez, C., Guzman, H. M., Isbell, F., Myers-Smith, I. H., Jones, H. P., Hines, J., Velland, M., Waldock, C., and O'connor, M. (2019). Species Richness Change Across Spatial Scales. Oikos, 128(8): 1079 – 1091.

Clelland, E. S., and Webster, N. B. (2021). Drilling into Hard Substrate by Naticid and Muricid Gastropods: A Chemo-Mechanical Process Involved in Feeding. (pp. 77 – 112). Apple Academic Press, New York, United States.

Chan, B. K., Wong, K. J., Cheng, Y. R., Thiel, M., and Poore, G. (2020). Biogeography and Host Usage of Coral-Associated Crustaceans: Barnacles, Copepods, and Gall Crabs as Model Organisms. The Natural History of the Crustacea: Evolution and Biogeography of the Crustacea, 8: 183 – 215.

Chen, E. Y. S. (2021). Often Overlooked: Understanding and Meeting the Current Challenges of Marine Invertebrate Conservation. Frontiers in Marine Science, 8: 1 – 20.

Chou, L. M., Wilkinson, C. R., Licuanan, W. R. Y., Alino, P., Cheshire, A. C., Loo, M. G. K., Tangjaitrong, S., Sudara, S., Ridzwan, A. R., and Soekarno, S. (1994). Status of Coral Reefs in the ASEAN Region. (pp. 16 – 20). Chulalongkorn University, Bangkok, Thailand.

Claremont, M., Reid, D. G., and Williams, S. T. (2011). Evolution of Corallivory in the Gastropod Genus *Drupella*. Coral Reefs, 30: 977 – 990.

Clelland, E. S., and Webster, N. B. (2021). Drilling into Hard Substrate by Naticid and Muricid Gastropods: A Chemo-Mechanical Process Involved in Feeding. (pp. 77 – 112). Apple Academic Press, New York, United States.

Cole, A. J., Pratchett, M. S., and Jones, G. P. (2008). Diversity and Functional Importance of Coral-Feeding Fishes on Tropical Coral Reefs. Fish and Fisheries, 9(3): 286 – 307.

Collin, R., and Ochoa, I. (2016). Influence of Seasonal Environmental Variation on the Reproduction of Four Tropical Marine Gastropods. Marine Ecology Progress Series, 555: 125 – 139.

Corte, G. N., Schlacher, T. A., Checon, H. H., Barboza, C. A., Siegle, E., Coleman, R. A., and Amaral, A. C. Z. (2017). Storm Effects on Intertidal Invertebrates: Increased Beta Diversity of Few Individuals and Species. PeerJ, 5: 1 – 18.

Couch, C. S., Oliver, T. A., Suka, R., Lamirand, M., Asbury, M., Amir, C., and Samson, J. (2021). Comparing Coral Colony Surveys from In-Water Observations and Structure-From-Motion Imagery Shows Low Methodological Bias. Frontiers in Marine Science, 8, 1 – 14.

Cozzoli, F., Shokri, M., Ligetta, G., Ciotti, M., Gjoni, V., Marrocco, V., Vignes, F., and Basset, A. (2020). Relationship Between Individual Metabolic Rate and Patch Departure Behaviour: Evidence from Aquatic Gastropods. Oikos, 129(11): 1657 – 1667.

Cumming, R. L. (2009). Case Study: Impact of *Drupella* spp. on Reef-Building Corals of the Great Barrier Reef. (pp. 1– 44). Report to the Great Barrier Reef Marine Park Authority.

Daud, N. R., and Akhir, M. F. M. (2015). Hydrodynamic Modelling of Bidong Island Vicinity Waters. Open Journal of Marine Science, 5: 306 – 323.

Daud, D., Annuar, N., and Nor, A. M. (2022). Conceptual Framework of Database Development on Bidong Island: The Case Vietnamese Boat People (VBP) Campsite Facilities for Historical Tourism. (pp. 19 – 28). Springer Nature Singapore, Singapore.

Déath, G., and Fabricius, K. (2010). Water Quality as a Regional Driver of Coral Biodiversity and Macroalgae on the Great Barrier Reef. Ecological Applications, 20(3): 840 – 850.

de Carvalho-Souza, G. F., and González-Ortegón, E. (2022). Scavenging Behavior by *Phyllonotus oculatus* (Gastropoda: Muricidae) in a South Atlantic Reef. Marine Biodiversity, 52(60): 1 – 2.

Dehens, L. A., and Fanning, L. M. (2018). What Counts in Making Marine Protected Areas (MPAs) Count? The Role of Legitimacy in MPA Success in Canada. Ecological Indicators, 86: 45 – 57.

Delgado, G. A., and Sharp, W. C. (2020). Capitalizing on an Ecological Process to Aid Coral Reef Ecosystem Restoration: Can Gastropod Trophodynamics Enhance Coral Survival? Coral Reefs, 39(2): 319 – 330.

Dennis, M. M., Molnár, K., Kriska, G., and Lőw, P. (2021). Mollusca: Gastropoda. (pp. 87 – 132). John Wiley and Sons, Hoboken, New Jersey.

Dhivaharan, V. (2021). Factors Influencing Molluscan (Gastropod) Populations in Thirumeni Lake, Tamil Nadu, India. Scientific Transactions in Environment and Technovation, 14(3): 100 – 129.

Dixon, A. M., Puotinen, M., Ramsay, H. A., and Beger, M. (2022). Coral Reef Exposure to Damaging Tropical Cyclone Waves in a Warming Climate. Earth's Future, 10(8): 1 – 17.

Donovan, M. K., Alves, C., Burns, J., Drury, C., Meier, O. W., Ritson-Williams, R., Cunning, R., Dunn, R. P., Goodbody-Gringley, G., Henderson, L. M., Knapp, I. S. S., Levy, J., Logan, C. A., Mudge, L., Sullivan, C., Gates, R. D., and Asner, G. P. (2023). From Polyps to Pixels: Understanding Coral Reef Resilience to Local and Global Change Across Scales. Landscape Ecology, 38(3): 737 – 752.

D'Souza, S. L., D'Souza, N., and Shenoy, K. B. (2022). Molluscan Diversity of Coastal Karnataka, India and Role of Physicochemical Parameters on Their Diversity. Journal of Coastal Conservation, 26(1): 1 – 15.

Dutra, L. X., Haywood, M. D., Singh, S., Ferreira, M., Johnson, J. E., Veitayaki, J., Kininmonth, S., Morris, C. W., and Piovano, S. (2021). Synergies Between Local and Climate-Driven Impacts on Coral Reefs in the Tropical Pacific: A Review of Issues and Adaptation Opportunities. Marine Pollution Bulletin, 164: 1 – 17.

Eklöf, J., Austin, Å., Bergström, U., Donadi, S., Eriksson, B. D., Hansen, J., and Sundblad, G. (2017). Size Matters: Relationships Between Body Size and Body Mass of Common Coastal, Aquatic Invertebrates in the Baltic Sea. PeerJ, 5: 1 –

14.

Fadliyah, S., Sari, L. A., Pursetyo, K. T., Zein, A., Idris, M. H., and Cahyoko, Y. (2021). The Variability in Population Structure of Gastropods in Sedati Waters, Sidoarjo Regency, East Java. IOP Conference Series: Earth and Environmental Science, 679: 1 – 7.

Fairoz, M. F. M. (2022). Coral Reefs and Blue Economy. Blue Economy: An Ocean Science Perspective (pp. 21 – 53). Springer Nature Singapore, Singapore.

Fasila, P., and Vinod, K. (2024). Comparative Feeding Ecology of *Turbo intercostalis* (Menke, 1846) and *Trochus radiatus* (Gmelin, 1791) from the Rocky Intertidal Area of Thikkodi, Southwest Coast of India. Records of the Zoological Survey of India, 575 – 582.

Fasila, P., Vinod, K., Asokan, P. K., and Jayachandran, P. R. (2024). Diversity and Distribution of Gastropods in the Seaweed-Dominated Rocky Intertidal Area of Thikkodi, Southwest Coast of India. Journal of the Marine Biological Association of India, 66(2): 16 – 23.

Feitosa, J. L., Miranda, R. J., and Queiroz-Véras, L. V. (2024). Herbivory and Competition for Space. Brazilian Coral Reefs: A Multidisciplinary Approach (pp. 113 – 142). Springer International Publishing, Brazil.

Fernández, N., Alborés, I., and Aceña-Matarranz, S. (2016). Spatial Variability of the Reproductive Cycle and Physiological Condition of *Patella* spp. (Mollusca Gastropoda) in the NW of the Iberian Peninsula: Implications for Exploitation. Fisheries Research, 179: 76 – 85.

Figueiredo, C. K., Duarte, R. C., and Flores, A. A. (2020). Ecosystem Functioning of Canopy-and Turf-Forming Algae: Contrasting Supply of Invertebrate Prey to Pelagic Consumers. Marine Ecology Progress Series, 647: 79 – 92.

Firdaus, M. A. A., Lim, C. S., Din, M. C., Kadir, S. T. S. A., Ramasamy, A. M. A., Ab Manaf, N., and Bachok, Z. (2021). Coral Reef Fish Community at Pulau Bidong, Terengganu, South China Sea. Journal of Sustainability Science and Management, 16(5): 48 – 66.

Floyd, M., Mizuyama, M., Obuchi, M., Sommer, B., Miller, M. G., Kawamura, I., and Beger, M. (2020). Functional Diversity of Reef Molluscs along a Tropical-to-Temperate Gradient. Coral Reefs, 39(5): 1361 – 1376.

Fordyce, A. J., Ainsworth, T. D., and Leggat, W. (2020). Microalgae, a Boring Bivalve and a Coral—A Newly Described Association Between Two Coral Reef Bioeroders Within Their Coral Host. Integrative Organismal Biology, 2(1): 1 – 9.

Fraser, K. M., Stuart-Smith, R. D., Ling, S. D., & Edgar, G. J. (2020). Small Invertebrate Consumers Produce Consistent Size Spectra Across Reef Habitats and Climatic Zones. Oikos, 130(1): 1 – 15.

Gautrand, L., Gairin, E., Sowinski, J., Sowinski, L., Krimou, S., Trotier, M., Minier, L., Chamot, Z., Gourlaouen, V., René-Trouillefou, M., Mills, S. C., Bertucci, F., and Lecchini, D. (2023). High Densities, Rapid Infestation and High Feeding Rates of Corallivore Gastropods on Corals in Bora-Bora Island, French Polynesia. Regional Studies in Marine Science, 66: 1 – 11.

Ghatpande, A. C., Nerurkar, S., and Apte, D. (2024). Taxonomic Records of *Tenguella granulata* (Duclos, 1832) and *Tenguella ceylonica* (Dall, 1923) (Mollusca: Gastropoda: Muricidae) from Alibag, Raigad, Maharashtra on the West Coast of India. CIBTech Journal of Zoology, 13: 1 – 15.

Gilmour, M. E., Adams, J., Block, B. A., Caselle, J. E., Friedlander, A. M., Game, E. T., and Wegmann, A. (2022). Evaluation of MPA Designs That Protect Highly Mobile Megafauna Now and Under Climate Change Scenarios. Global Ecology and Conservation, 35: 1 – 19.

Gittenberger, A., Draisma, S. G., Arbi, U. Y., Langenberg, V., Erftemeijer, P. L., Tuti, Y., and Hoeksema, B. W. (2015). Coral Reef Organisms as Bioregion Indicators off Halmahera, Moluccas, Indonesia. Aquatic Conservation: Marine and Freshwater Ecosystems, 25(6): 743 – 755.

Glynn, P. W., and Enochs, I. C. (2010). Invertebrates and Their Roles in Coral Reef Ecosystems. (pp. 273 – 325). Springer Science and Business Media: Australia.

González, J. E. A., Fung, T., Seymour, R. M., Garza-Pérez, J. R., Acosta-González, G., Bozec, Y. M., and Johnson, C. R. (2017). A Coral-Algal Phase Shift in Mesoamerica Not Driven by Changes in Herbivorous Fish Abundance. Plos One, 12(4): 1 – 17.

Good, A. M., and Bahr, K. D. (2021). The Coral Conservation Crisis: Interacting Local and Global Stressors Reduce Reef Resiliency and Create Challenges for Conservation Solutions. SN Applied Sciences, 3(3): 1 – 14.

Graham, N. A. J., Ainsworth, T. D., Baird, A. H., Ban, N. C., Bay, L. K., Cinner, J. E., De Freitas, D. M., Dia-Pulido, G., Dornelas, M., Dunn, S. R., Fidelman, P. I. J., Foret, S., Good, T. C., Kool, J., Mallela, J., Penin, L., Pratchett, M. S., and Williamson, D. H. (2011). From Microbes to People: Tractable Benefits of No-

Take Areas for Coral Reefs. Oceanography and Marine Biology, 49: 105 – 135.

Grismer, L. L., Wood Jr, P. L., and Ahmad, A. B. (2014). A New Species of Insular Rock Gecko (Genus *Cnemaspis* Strauch, 1887) from the Bidong Archipelago, Terengganu. Zootaxa, 3755(5): 447 – 456.

Grizzetti, B., Liquete, C., Pistocchi, A., Vigiak, O., Zulian, G., Bouraoui, F., and Cardoso, A. C. (2019). Relationship Between Ecological Condition and Ecosystem Services in European Rivers, Lakes and Coastal Waters. Science of the Total Environment, 671: 452 – 465.

Grorud-Colvert, K., Sullivan-Stack, J., Roberts, C., Constant, V., Horta e Costa, B., Pike, E. P., and Lubchenco, J. (2021). The MPA Guide: A Framework to Achieve Global Goals for the Ocean. Science, 373(6560): 1 – 38.

Hadiyanto, H., Arbi, U. Y., Juanda, R., Subandi, R., and Sjafrie, N. D. M. (2022). Evaluation of the Effect of a Marine Protected Area on Rocky Intertidal Molluscs in Weh Island, Indonesia. International Journal of Conservation Science, 13(1): 307 – 320.

Hamman, E. A. (2018). Aggregation Patterns of Two Corallivorous Snails and Consequences for Coral Dynamics. Coral Reefs, 37(3): 851 – 860.

Hammer, Ø., Harper, D. A. T., and Ryan, P. D., (2001). Past: Paleontological Statistics Software Package for Education and Data Analysis. Palentologia Electronica, 4(1): 1 – 9.

Hardy's Internet Guide to Marine Gastropods (2021). Retrieved from https://conchology.be/?t=4041

Haslam, V. M., Bessey, C., Chaplin, J. A., and van Keulen, M. (2023). Evidence of Corallivorous Gastropod *Drupella cornus* Breeding on the Higher Latitude Reefs of Rottnest Island (32° S), Western Australia. Marine Biology, 171(1): 1 – 16.

Haslam, V. M., Maroni, P. J., Chaplin, J. A., Bessey, C., and van Keulen, M. (2025). High Levels of Genetic Connectivity in the Corallivorous Gastropod *Drupella cornus* (Röding, 1798) in an Expanding Latitudinal Range along Western Australia. Marine Biodiversity, 55(1): 1 – 18.

Haumahu, S., Uneputty, P. A., and Lewerissa, Y. A. (2020). Growth and Potential Reproductive of Gastropod *Strombus luhuanus* Linneaus, 1758 Inhabit Oma Coastal Waters, Central Maluku, Indonesia. International Journal of Fisheries and Aquatic Studies, 8(1): 32 – 36.

Henry, J. A., O'Neil, K. L., and Patterson, J. T. (2019). Native Herbivores Improve Sexual Propagation of Threatened Staghorn Coral *Acropora cervicornis*. Frontiers in Marine Science, 6: 1 – 8.

Herbert, G. S., Geiger, S. P., Hesterberg, S. G., Seiden, N., Rogers, J. A., Harke, R. M., and Goddard, E. A. (2022). Age and Growth of One of the World's Largest Carnivorous Gastropods, the Florida Horse Conch, *Triplofusus giganteus* (Kiener, 1840), a Target of Unregulated, Intense Harvest. Plos One, 17(4): 1 – 17.

Herbert, G. S., Hesterberg, S. G., and Geiger, S. P. (2023). Life History Traits of the Herbivorous Marine Gastropods *Turbo castanea* and *Lithopoma americanum*, Harvested for the Florida Ornamental Aquarium Trade. Journal of Shellfish Research, 42(1): 99 – 103.

Hilmi, E., Sari, L. K., Cahyo, T. N., Dewi, R., and Winanto, T. (2022). The Structure Communities of Gastropods in the Permanently Inundated Mangrove Forest on the North Coast of Jakarta, Indonesia. Biodiversitas, 23(5): 2699 – 2710.

Hoegh-Guldberg, O., Pendleton, L., and Kaup, A. (2019). People and the Changing Nature of Coral Reefs. Regional Studies in Marine Science, 30: 1 – 20.

Hoeksema, B. W., Scott, C., and True, J. D. (2013). Dietary Shift in Corallivorous *Drupella* Snails Following a Major Bleaching Event at Koh Tao, Gulf of Thailand. Coral Reefs, 32(2): 423 – 428.

Hoeksema, B. W., Harper, C. E., Langdon-Down, S. J., van der Schoot, R. J., Smith-Moorhouse, A., Spaargaren, R., and Timmerman, R. F. (2022). Host Range of the Coral-Associated Worm Snail *Petaloconchus* sp. (Gastropoda: Vermetidae), a Newly Discovered Cryptogenic Pest Species in the Southern Caribbean. Diversity, 14(3): 1 – 8.

Hong, T. C., Borkhanuddin, M. H., Jaafar, S. N., Kamarudin, N., and Noor, M. M. R. H. (2020). Coral Reef Benthic Communities Using Coral Video Transect. (pp. 6 – 35). Post COVID-19 Marine Life Status at Marine Parks Islands of Terengganu Report.

Hossain, M. R. A., Pramanik, M. M. H., and Hasan, M. M. (2017). Diversity Indices of Plankton Communities in the River Meghna of Bangladesh. International Journal of Fisheries and Aquatic Studies, 5(3): 330 – 334.

Hossain, M. M., and Staples, A. E. (2020). Effects of Coral Colony Morphology on Turbulent Flow Dynamics. Plos One, 15(10): 1 – 25.

Houart, R., Gori, S., and Rosado, J. (2017). The Muricidae (Gastropoda: Muricoidea) from Oman with the Description of Four New Species. Novapex, 18(3): 41– 69.

IDTools (2022). Measuring Terrestrial Gastropods. Retrieved from https://idtools.org/identify.cfm?sort=dateDesc

Ilias, N., Hwai, A. T. S., Rick, F., Peng, T. C., Nilamani, N., Razalli, N. H., and Yasin, Z. (2021). Diversity of Epibenthic Intertidal Molluscan Communities on the Seagrass Beds of Middle Bank, Penang, Malaysia. Phuket Marine Biological Center Research Bulletin, 78: 39 – 47.

Isdianto, A., Amanda, S. S., Yamindago, A., Dewi, C. S. U., Aliviyanti, D., Luthfi, O. M., and Puspitasari, I. D. (2024). Water Quality Impact Christmas Tree Worms (*Spirobranchus* spp.) Distribution and Community Structure on Hard Corals at Sempu Island Nature Reserve, Malang, Indonesia. Journal of Ecological Engineering, 25(5): 175 – 186.

Islam, G. M. N., Noh, K. M., Yew, T. S., and Noh, A. F. M. (2013). Assessing Environmental Damage to Marine Protected Area: A Case of Perhentian Marine Park in Malaysia. Journal of Agricultural Science, 5(8): 132 – 141.

Isroni, W., Sari, P. D., Sari, L. A., Daniel, K., South, J., Islamy, R. A. Wirabuana, P. Y. A. P., and Hassan, V. (2023). Checklist of Mangrove Snails (Gastropoda: Mollusca) on the Coast of Lamongan District, East Java, Indonesia. Biodiversitas, 24(3): 1676 – 1685.

Iwasaki, S., Inoue, M., Suzuki, A., Sasaki, O., Kano, H., Iguchi, A., Sakai, K., and Kawahata, H. (2016). The Role of Symbiotic Algae in the Formation of the Coral Polyp Skeleton: 3-D Morphological Study Based on X-ray Microcomputed Tomography. Geochemistry, Geophysics, Geosystems, 17(9): 3629 – 3637.

Jaafar, M., and Maideen, S. A. (2012). Ecotourism-Related Products and Activities, and the Economic Sustainability of Small and Medium Island Chalets. Tourism Management, 33(3): 683 – 691.

Jurkiewicz-Karnkowska, E. (2009). Diversity of Aquatic Malacofauna within a Floodplain of a Large Lowland River (Lower Bug River, Eastern Poland). Journal of Molluscan Studies, 75(3): 223 – 234.

Jones, R., Fisher, R., and Bessell-Browne, P. (2019). Sediment Deposition and Coral Smothering. Plos One, 14(6): 1 – 24.

Joy, A., and Gopinath, A. (2021). The Application of Reefs in Shoreline

Protection. Handbook of Ecological and Ecosystem Engineering. (pp. 295 – 315). Wiley, University of Hyderabad.

Kahng, S. E., Akkaynak, D., Shlesinger, T., Hochberg, E. J., Wiedenmann, J., Tamir, R., and Tchernov, D. (2019). Light, Temperature, Photosynthesis, Heterotrophy, and the Lower Depth Limits of Mesophotic Coral Ecosystems. Mesophotic Coral Ecosystems, 801 – 828.

Kamalakannan, B., Jeevamani, J. J. J., Nagendran, N. A., Pandiaraja, D., and Chandrasekaran, S. (2014). Impact of Removal of Invasive Species *Kappaphycus alvarezii* from Coral Reef Ecosystem in Gulf of Mannar, India. Current Science, 106(10): 1401 – 1408.

Kamaludin, M., Haron, N. F., Ridzuan, A. R., and Azlina, A. A. (2021). Assessing Visitors' Willingness to Pay (WTP) for Coral Reef Conservation Program in Perhentian Island, Terengganu, Malaysia. Journal of Business and Social Development, 9(2): 79 – 92.

Kamerman, T. Y. (2023). The Potential for Top-Down Control of the Corallivorous Gastropod *Coralliophila galea* and Its Effect on Coral Reef Ecosystems (Master Dissertation).

Kaullysing, D., Mehrotra, R., Arnold, S., Ramah, S., Allchurch, A., Haskin, E., Taleb-Hossenkhan, N., and Bhagooli, R. (2020). Multiple Substrates Chosen in Mass in situ Egg Deposition by *Drupella* in Mauritius, a First Record for the Western Indian Ocean. Journal of Molluscan Studies, 86(4): 427 – 430.

Kee, A. A. A., Wong, W. S., Badrul, H., and Affendi, Y. A. (2005). Macroinvertebrate Diversity of Kg. Tekek, Pulau Tioman Marine Park. Proceedings of the Second Regional Symposium on Environment and Natural Resources, 2: 79 – 84.

Khalifa, G. M., Levy, S., and Mass, T. (2021). The Calcifying Interface in a Stony Coral Primary Polyp: An Interplay Between Seawater and an Extracellular Calcifying Space. Journal of Structural Biology, 213(4): 1 – 14.

Kim, T. (2013). Determining the Abundance, Density, Population Structure, and Feeding Preference of *Drupella* Snails on Koh Tao, Thailand (Bachelor dissertation).

Kita, M., Kitamura, M., Koyama, T., Teruya, T., Matsumoto, H., Nakano, Y., and Uemura, D. (2005). Feeding Attractants for the Muricid Gastropod *Drupella cornus,* a Coral Predator. Tetrahedron Letters, 46(49): 8583 – 8585.

Kitamura, T., Shigematsu, Y., Iwai, T., Miura, C., and Miura, T. (2022). The Spawning Season of *Drupella fragum* in Southwestern Shikoku. Biogeography, 24: 32 – 38.

Knoester, E. G. (2023). Facilitating the Facilitators: Advancing Coral Reef Restoration by Considering Ecological Keystone Species (Doctoral Dissertation).

Kramer, N., Tamir, R., Galindo-Martínez, C. T., Wangpraseurt, D., and Loya, Y. (2023). Light Pollution Alters the Skeletal Morphology of Coral Juveniles and Impairs Their Light Capture Capacity. Marine Pollution Bulletin, 193: 1 – 9.

Krebs, C. J. (1972). Ecologically Methodology. (pp. 624). Harper Collins Publisher, New York, United States.

Krebs, C. J. (1978). Methods for Analyzing Distributions. (pp. 32 – 41). Benjamin Cummings, San Francisco, Northern California.

Kroon, F. J., Barneche, D. R., and Emslie, M. J. (2021). Fish Predators Control Outbreaks of Crown-of-Thorns Starfish. Nature Communications, 12(1): 1 – 10.

Kuanui, P., Chavanich, S., Viyakarn, V., Omori, M., Fujita, T., and Lin, C. (2020). Effect of Light Intensity on Survival and Photosynthetic Efficiency of Cultured Corals of Different Ages. Estuarine, Coastal and Shelf Science, 235: 1 – 6.

Kurniawan, D., Putra, R. D., Siringoringo, R. M., Sari, N. W. P., Abrar, M., Jumsurizal, J., Febrianto, T., and Hasnarika, H. (2023). Conditions of Megabenthos on Coral Reef Ecosystem in Seribu Islands National Park, Jakarta, Indonesia. BIO Web of Conferences, 70: 1 – 11.

Lachs, L., Johari, N. A. M., Le, D. Q., Safuan, C. D. M., Duprey, N. N., Tanaka, K., Hong, T. C., Ory, N. C., Bachok, Z., Baker, D. M., Kochzius, M., and Shirai, K. (2019). Effects of Tourism-Derived Sewage on Coral Reefs: Isotopic Assessments Identify Effective Bioindicators. Marine Pollution Bulletin, 148: 85 – 96.

Lah, R. A., Bucher, D., Savins, D., Dowell, A., and Benkendorff, K. (2019). Temporal Variation in Condition Index and Meat Quality of *Lunella undulata* (Turbinidae), in Relation to the Reproductive Cycle. Molluscan Research, 39(2): 122 – 139.

Laheng, S., Putri, D. U., and Putri, I. W. (2023). Diversity of Gastropods in Kapas Island, Indonesia. Marine and Fishery Sciences (MAFIS), 36(1): 101 – 108.

Lee, J. N., Norizam, M. M., and Yusuf, Y. (2020). Coral Reefs Health: View from

Benthic and Fish Populations. (pp. 57 – 66). Post COVID-19 Marine Life Status at Marine Parks Islands of Terengganu Report.

Lee, J. N., Abd Adzis, K. A., Afiq-Rosli, L., Tanzil, J. T., Chan, A. A., Ismail, M. N., Akmal, A. F., and Affendi, Y. A. (2022). Scleractinian Coral (Cnidaria, Hexacorallia, Scleractinia) Diversity of the Mersing Islands, Peninsular Malaysia. ZooKeys, 1102: 177 – 190.

Lei, X., Liu, C., Zhang, Y., Yu, X., Yang, J., Luo, Y., Zhou, G., and Huang, H. (2022). Spatial Variability in the Abundance and Prey Selection of the Corallivorous Snail *Drupella* spp. in the Southeastern Hainan Island, China. Frontiers in Marine Science, 9: 1 – 13.

Li, Q., Yang, L., Ke, Q., and Kong, L. (2011). Gametogenic Cycle and Biochemical Composition of the Clam *Mactra chinensis* (Mollusca: Bivalvia): Implications for Aquaculture and Wild Stock Management. Marine Biology Research, 7(4): 407 – 415.

Li, X., Song, H., Tian, L., Chen, X., Sun, X., Yan, J., and Chu, D. (2025). The Impact of Ocean Acidification on Gastropod Shell Dissolution and Microstructure. Anthropocene, 50: 1 – 11.

Loke, L. H., and Chisholm, R. A. (2022). Measuring Habitat Complexity and Spatial Heterogeneity in Ecology. Ecology Letters, 25(10): 2269-2288.

Linsmayer, L. B., Deheyn, D. D., Tomanek, L., and Tresguerres, M. (2020). Dynamic Regulation of Coral Energy Metabolism throughout the Diel Cycle. Scientific Reports, 10(1): 1 – 11.

Lippens, C. R., and Banaszak, A. T. (2025). Integrating Grazing and Food Supplementation in Coral Restoration to Enhance Settler Survival and Growth. Restoration Ecology, 33(1): 1 – 11.

Lugo-Fernández, A., Roberts, H. H., and Wiseman, W. J. J. (2004). Currents, Water Levels, and Mass Transport over a Modern Caribbean Coral Reef: Tague Reef, St. Croix, USVI. Continental Shelf Research, 24(17): 1989 – 2009.

Luthfi, O. M., and Priyambodo, A. H. (2020). Bioerosion in Massive *Porites* at Reef Flat Area of the South Java Sea. IOP Conference Series: Earth and Environmental Science, 420: 1 – 10.

MacNeil, M. A., Mellin, C., Matthews, S., Wolff, N. H., McClanahan, T. R., Devlin, M., and Graham, N. A. (2019). Water Quality Mediates Resilience on the Great

Barrier Reef. Nature Ecology and Evolution, 3(4): 620-627.

Magurran, A. E. (2004). Measuring Biological Diversity. (pp. 1 – 248). Blackwell Science Ltd, Oxford, United Kingdom.

Marsden, I. D., and Baharuddin, N. (2015). Gastropod Growth and Survival as Bioindicators of Stress Associated with High Nutrients in the Intertidal of a Shallow Temperate Estuary. Estuarine, Coastal and Shelf Science, 156: 175 – 185.

Marshall, D. J., and McQuaid, C. D. (2020). Metabolic Regulation, Oxygen Limitation and Heat Tolerance in a Subtidal Marine Gastropod Reveal the Complexity of Predicting Climate Change Vulnerability. Frontiers in Physiology, 11, 1 – 12.

Marzo, R. R., Chen, H. W. J., Anuar, H., Wahab, M. K. A., Nizam, M. H., Ariffin, I. A., Hamzah, H., Ahmad, A. I., Kawuki, J., Halim, S., and Aljuaid, M. (2023). Knowledge, Attitude, and Practice of Coral Reef Conservation Among Terengganu Community of Malaysia. Frontiers in Environmental Science, 11: 1 – 11.

Masanja, F., Jiang, X., Wang, Y., and Zhao, L. (2024). Impacts of Ocean Acidification on the Behavior of Marine Mollusks. Ecophysiology and Ocean Acidification in Marine Mollusks (pp. 199 – 224). Academic Press, China.

Masud, M. M. (2019). Conservation of Marine Resources and Sustainable Coastal Community Development in Malaysia: Conservation of Marine Resources and Sustainable Coastal Community Development in Malaysia (pp. 7 – 26). Palgrave Pivot: Singapore.

Masud, M. M., Shahabudin, S. M., Baskaran, A., and Akhtar, R. (2022). Co-Management Approach to Sustainable Management of Marine Protected Areas: The Case of Malaysia. Marine Policy, 138: 1 – 11.

Maxwell, S. J., Rymer, T. L., and Congdon, B. C. (2021). A Theoretical Composite Model for Population Sex-Specific Shell Size Dynamics in Strombidae (Gastropoda, Neostromboidae). Journal of Natural History, 55: 2661 – 2672.

Mbije, N. E., Douek, J., Spanier, E., and Rinkevich, B. (2019). Population Genetic Parameters of the Emerging Corallivorous Snail *Drupella cornus* in the Northern Gulf of Eilat and Tanzanian Coastlines Based on Mitochondrial COI Gene Sequences. Marine Biodiversity, 49: 147 – 161.

McAfee, A. (2017). Importance of Islands as Protected Bird Species Reservoirs

Around Terengganu. (pp. 230 – 246). Department of Wildlife and National Parks (Perhilitan) Peninsular Malaysia, Kuala Lumpur, Malaysia.

McClanahan, T. R. (1997). Dynamics of *Drupella cornus* Populations on Kenyan Coral Reefs. Proceedings of the 8th International Coral Reef Symposium, 1: 633 – 638.

McIlwain, J. L., and Jones, G. P. (1997). Prey Selection by an Obligate Coral-Feeding Wrasse and its Response to Small-Scale Disturbance. Marine Ecology Progress Series, 155, 189 – 198.

McManus, J. W., and Polsenberg, J. F. (2004). Coral–Algal Phase Shifts on Coral Reefs: Ecological and Environmental Aspects. Progress in Oceanography, 60: 263 – 279.

McMullin, R. M., Miller, M. R., Fletcher, L. M., and Hopkins, G. A. (2024). Biochemical Composition of Biofilms and Gastropod Grazers; Informing Biological Control Efforts from a Nutritional Perspective. New Zealand Journal of Marine and Freshwater Research, 59(4): 886 – 911.

Mehrotra, R., Caballer, M., Kaullysing, D., Jualaong, S., and Hoeksema, B. W. (2024). Parasites or Predators? Gastropod Ectoparasites and Their Scleractinian Host Corals at Koh Tao, Gulf of Thailand, with the Description of a New Species. Symbiosis, 92(2): 209 – 230.

Mercado-Molina, A. E., Sabat, A. M., and Hernández-Delgado, E. A. (2020). Population dynamics of diseased corals: Effects of a Shut Down Reaction outbreak in Puerto Rican *Acropora cervicornis*. Advances in Marine Biology, 87(1): 61 – 82.

Mérot, C., and Collin, R. (2012). Effects of Stress on Sex Change in *Crepidula* cf. *marginalis* (Gastropoda: Calyptraeidae). Journal of Experimental Marine Biology and Ecology, 416: 68 – 71.

Meyer, C. P., Geller, J. B., and Paulay, G. (2005). Fine Scale Endemism on Coral Reefs: Archipelagic Differentiation in Turbinid Gastropods. Evolution, 59(1): 113 – 125.

Mies, M., Banha, T. N., Castro, C. B., Cordeiro, R. T., Lotufo, T. M., and Bianchini, A. (2024). Biology of Brazilian Benthic Reef Builders and Dwellers. Brazilian Coral Reefs: A Multidisciplinary Approach. (pp. 81 – 112). Springer Nature Switzerland, Switzerland.

Ministry of Natural Resources and Environment (2016). National Policy on Biological Diversity 2016 – 2025 (pp. 1 – 111). Natural Resources Environment, Malaysia.

Moerland, M. S., Scott, C. M., and Hoeksema, B. W. (2016). Prey Selection of Corallivorous Muricids at Koh Tao (Gulf of Thailand) Four Years After a Major Coral Bleaching Event. Contributions to Zoology, 85(3): 291 – 309.

Mohanraj, J., Chelladurai, G., Balakrishnan, S., and Kuam, I. V. (2015). Gulf of Mannar Island Coral Reef Associated Gastropods Assemblages: Distribution and Diversity Pattern. Journal of Coastal Life Medicine, 3(9): 691 – 695.

Mokhtar, M. Z., Adrianza, M. A., and Zulkifli, H. S. (2020). Cost-Benefit Analysis on Marine Parks in Terengganu. Journal of Business and Social Development, 8: 1 – 12.

Montano, S., Aeby, G., Galli, P., and Hoeksema, B. W. (2022). Feeding Behavior of *Coralliophila* sp. on Corals Affected by Caribbean Ciliate Infection (CCI): A New Possible Vector? Diversity, 14: 1 – 4.

Moran, M. J. (1985). Distribution and Dispersion of the Predatory Intertidal Gastropod *Morula marginalba.* Marine Ecology Progress Series, 22: 41 – 52.

Moretzsohn, F. (2023). Shells: A Natural and Cultural History (pp. 1 – 54). Reaktion Books, England.

Morillo-Velarde, P. S., Briones-Fourzán, P., Álvarez-Filip, L., Aguíñiga-García, S., Sánchez-González, A., and Lozano-Álvarez, E. (2018). Habitat Degradation Alters Trophic Pathways but Not Food Chain Length on Shallow Caribbean Coral Reefs. Scientific Reports, 8(1): 1 – 12.

Morton, B., Blackmore, G., and Kwok, C. T. (2002). Corallivory and Prey Choice by *Drupella rugosa* (Gastropoda: Muricidae) in Hong Kong. Journal of Molluscan Studies, 68(3): 217 – 223.

Morton, B., and Blackmore, G. (2009). Seasonal Variations in the Density of and corallivory by *Drupella rugosa* and *Cronia margariticola* (Caenogastropoda: Muricidae) from the Coastal Waters of Hong Kong: 'Plagues' or 'Aggregations'? Journal of the Marine Biological Association of the United Kingdom, 89(1): 147 – 159.

Motti, C. A., Cummins, S. F., and Hall, M. R. (2022). A Review of the Giant Triton (*Charonia tritonis*), from Exploitation to Coral Reef Protector? Diversity, 14, 1 – 35.

Mujiono, N. (2020). Checklist of Gastropoda from Lombok Island and its Satellite Islands. Jurnal Biologi Udayana, 24(2): 72 – 86.

Munian, K., Azman, S. M., Ruzman, N. A., Fauzi, N. F. M., and Zakaria, A. N. (2020). Diversity and Composition of Volant and Non-Volant Small Mammals in Northern Selangor State Park and Adjacent Forest of Peninsular Malaysia. Biodiversity Data Journal, 8: 1 – 21.

Munk, N. J. (2024). Host and Symbiont Physiology During Wound Regeneration in *Acropora pulchra* Under Warming Conditions (Master Dissertation).

Nama, S., Shanmughan, A., Nayak, B. B., Bhushan, S., and Ramteke, K. (2023). Impacts of Marine Debris on Coral Reef Ecosystem: A Review for Conservation and Ecological Monitoring of the Coral Reef Ecosystem. Marine Pollution Bulletin, 189: 1 – 13.

Nasir, N. M., Ibrahim, M., Mahamod, L. H., and Othman, R. (2017). Challenges to Implement Carrying Capacity Framework: A Case Study of Pulau Perhentian Marine Park Institutional Framework. Planning Malaysia, 15(1): 163 – 168.

Neil, R. C., Barton, J. A., Dougan, W., Dworjanyn, S., Heyward, A., Mos, B., and Humphrey, C. (2024). Size Matters: Microherbivores Make a Big Impact in Coral Aquaculture. Aquaculture, 581: 1 – 10.

Niz, W. C., Laurino, I. R., de Freitas, D. M., Rolim, F. A., Motta, F. S., and Pereira-Filho, G. H. (2023). Modeling Risks in Marine Protected Areas: Mapping of Habitats, Biodiversity, and Cultural Ecosystem Services in the Southernmost Atlantic Coral Reef. Journal of Environmental Management, 345, 1 – 13.

Nützel, A. (2021). Gastropods as Parasites and Carnivorous Grazers: A Major Guild in Marine Ecosystems. The Evolution and Fossil Record of Parasitism: Identification and Macroevolution of Parasites (pp. 209 – 229). Springer Nature Switzerland, Switzerland.

Obaza, A., and Ruehl, C. B. (2013). Regressions for Estimating Gastropod Biomass with Multiple Shell Metrics. Malacologia, 56: 343 – 349.

Oren, U., Brickner, I., and Loya, Y. (1998). Prudent Sessile Feeding by the Corallivore Snail, *Coralliophila violacea* on Coral Energy Sinks. Proceedings Royal Society London B, 265: 2043 – 2050.

Osinga, R., Schutter, M., Griffioen, B., Wijffels, R. H., Verreth, J. A. J., Shafir, S., Henard, S., Taruffi, M., Gili, C., and Lavorano, S. (2011). The Biology and

Economics of Coral Growth. Marine Biotechnology, 13: 658 – 671.

Pawlik, J. R., and McMurray, S. E. (2020). The Emerging Ecological and Biogeochemical Importance of Sponges on Coral Reefs. Annual Review of Marine Science, 12(1): 315 – 337.

Perry, C. T., and Larcombe, P. (2003). Marginal and Non-Reef-Building Coral Environments. Coral Reefs, 22: 427 – 432.

Pisapia, C., Stella, J., Silbiger, N. J., and Carpenter, R. (2020). Epifaunal Invertebrate Assemblages Associated with Branching Pocilloporids in Moorea, French Polynesia. PeerJ, 8: 1 – 19.

Prieto-Amador, M., and Palomar-Abesamis, N. (2024). Insights on Evaluating Commercially Important Macroinvertebrate Species in Danjugan Island Marine Reserve, Philippines. Philippine Journal of Science, 153(3): 757 – 768.

Rahman, M. A. A., Ghazali, F., Rusli, M. H. M., Aziz, N., and Asma, W. I. A. (2019). Marine Protected Areas in Peninsular Malaysia: Shifting from Political Process to Co-Management. Journal Politics and Law, 12: 22 – 30.

Rahmayanti, F., Nazira, F. K., Dewi, A. K., Oktaviani, D. F., Millaty, I. N. K., Prasetya, T. A., Sasmita, H. B., Nashrurrokhman, M., Roshitafandi, D. A., Febiansi, D., Sartika, H. W., Zulfikar, W. G., Kurnia, R. N., Islami, D. A., and Tranggono, Y. A. (2018). Biodiversity of Gastropod in the Sombu Beach, Wakatobi, Indonesia. IOP Conference Series: Earth and Environmental Science, 139: 1 – 5.

Rani, P., and Roy, P. (2025). Reef Predators Unveiled: Unraveling Corallivores' Influence on Coral Reef Ecosystems. Computational and Applied Mathematics, 44(1): 1 – 54.

Rao, Y. P., Devi, V. U., and Rao, D. G. V. P. (1988). Seasonal Changes in the Level and Content of Different Biochemical Constituents in Tropical Cerithiids *Cerithidea* (*Cerithideopsilla*) *cingulata* (Gmelin 1790) and *Cerithium coralium* Kiener 1841. Proceedings Indian Academy Sciences (Animal Sciences), 97: 151 – 160.

Ratianingsih, R., Ismawati, N., Puspita, J. W., and Jaya, A. I. (2017). The Role of Top-Predator in the Preservation of Coral Reefs Ecosystem. Communication Biomathematical Sciences, 1: 54 – 61.

Ratibou, Z., Inguimbert, N., and Dutertre, S. (2024). Predatory and Defensive

Strategies in Cone Snails. Toxins, 16(2): 1 – 30.

Raymundo, L. J., Work, T. M., Miller, R. L., and Lozada-Misa, P. L. (2016). Effects of *Coralliophila violacea* on Tissue Loss in the Scleractinian Corals *Porites* spp. Depend on Host Response. Diseases of Aquatic Organisms, 119(1): 75 – 83.

Razak, F., Lua, W. Y., Abd Rasid, N. H., Aziz, N., Repin, I. M., Xue, X. Z., Muhammad Asraf, A. R., Bachok, Z., Firdaus, A. A., Taalat, W. I. A. W., Latip. A. R. A., and Safuan, C. D. M. (2024). Adopting Marine Spatial Planning (MSP) Using Coral Health Assessment as Indicator: A Case Study in Pulau Redang Marine Park, Malaysia. Ocean and Coastal Management, 248, 1 – 11.

Reef Check Malaysia, (2020). Status of Coral Reefs in Malaysia, 2020. (pp. 1 – 124). Reef Check Malaysia.

Rees, W. E. (1992). Ecological Footprints and Appropriated Carrying Capacity: What Urban Economics Leaves Out. Environment and Urbanization, 4(2): 121– 130.

Renzi, J. J., Shaver, E. C., Burkepile, D. E., and Silliman, B. R. (2022). The Role of Predators in Coral Disease Dynamics. Coral Reefs, 41(2): 405 – 422.

Rice, M. M., Ezzat, L., and Burkepile, D. E. (2019). Corallivory in the Anthropocene: Interactive Effects of Anthropogenic Stressors and Corallivory on Coral Reefs. Frontiers in Marine Science, 5: 1 – 14.

Richard, K. N., Hunsucker, K. Z., Hunsucker, T. and Swain, G. (2024). The Benefits of Biofouling–Promoting the Growth of Benthic Organisms to Enhance Ecosystem Services. Journal of Ecological Engineering, 25(9): 133 – 155.

Ridzuan, I., Talib, M. A., and Keetanjaly, A. (2022). Reassessment of Malaysia's Tourism Policy on Bidong Island. International Journal of Academic Research in Business and Social Science, 12(8): 63 – 75.

Riera, E., Mauroy, B., Francour, P., and Hubas, C. (2024). Establishing Complexity Targets to Enhance Artificial Reef Designs. Scientific Reports, 14(1): 1 – 11.

Rinkevich, B. (2021). Ecological Engineering Approaches in Coral Reef Restoration. ICES Journal of Marine Science, 78(1): 410 – 420.

Risk, M. J., and Edinger, E. (2011). Impacts of Sediment on Coral Reefs. (pp. 575 – 586). Springer Science and Business Media, Netherlands.

Rivera, H., Chan, A., and Luu, V. (2020). Coral Reefs Are Critical or our food supply, tourism, and ocean health. We can protect them from climate change. MIT Science Policy Review, 1, 18 – 33.

Rizmaadi, M., Riter, J., Fatimah, S., Rifaldi, R., Yoga, A., Ramadhan, F., and Ambariyanto, A. (2018). Community Structure of Coral Reefs in Saebus Island, Sumenep District, East Java. E3S Web of Conferences, 31: 1 – 6.

Roseli, N. H., and Akhir, M. F. M. (2014). Variations of Southern South China Sea Characteristics near Pahang. Sains Malaysiana, 43(9): 1389 – 1396.

Roseli, N. H., Akhir, M. F., Husain, M. L., Tangang, F., and Ali, A. (2015). Water Mass Characteristics and Stratification at the Shallow Sunda Shelf of Southern South China Sea. Open Journal of Marine Science, 5(4): 455 – 467.

Ruan, Y. (2021). Outbreak and Prevention of *Drupa* and *Drupella*. IOP Conference Series: Earth and Environmental Science, 78: 1 – 6.

Safuan, C. D. M., Roseli, N. H., Bachok, Z., Akhir, M. F., Xia, C., and Qiao, F. (2020). First Record of Tropical Storm (Pabuk-January 2019) Damage on Shallow Water Reef in Pulau Bidong, South of South China Sea. Regional Studies in Marine Science, 35: 1 – 12.

Safuan, C. D. M., Ashraf, A. R. M., Tan, C. H., Jaafar, S. N., Yusop, P. A. M., Lai, R. K., Md, N. I., Chan, A. A., Repin, I. M., Wee, H. B., and Bachok, Z. (2021). Coral Health Status Assessment in Malaysia Islands; Looking Towards Marine Spatial Planning. Ocean and Coastal Management, 213: 1 – 10.

Safuan, C. D. M., Aziz, N., Repin, I. M., Xue, X. Z., Abdul Rahman, M. A., and Bachok, Z. (2022). Assessment of Governance and Ecological Status of Terengganu Marine Park, Malaysia: Toward Marine Spatial Planning. Sains Malaysiana, 51(12): 3909 – 3922.

Sakilan, J. M. (2021). Assessment of Conus Species: Gastropoda: Conidae at selected shorelines of Sulu, Philippines. Journal of Biodiversity and Environmental Sciences (JBES), 18, 96 – 101.

Saleh, E., Kiat, Y. T., Geng, C. N., Masidi, A. M., and Joseph, J. (2020). Inventory of Marine Fauna on Reef Balls Structures of Selingan Island, Sandakan, Sabah, Malaysia. Journal of Tropical Biology and Conservation, 17, 203 – 216.

Salleh, S. M., Nishizawa, H., Sah, S. M., Chowdhury, A. J., and Rusli, M. U. (2021). Sand Particle Size Influences Nest Site Selection of Green Turtles (*Chelonia* *mydas*) Differently in East and West Peninsular Malaysia. Herpetological Conservation and Biology, 16(3), 671 – 680.

Sam, S. Q., Kikuzawa, Y. P., Taira, D., Ng, C. S. L., Toh, T. C., and Chou, L. M. (2016). First Observation of *Drupella* rugosa Egg Capsules on Scleractinian Coral *Pocillopora damicornis*. Bulletin of Marine Science, 92(3): 353 – 354.

Sam, S. Q., Toh, T. C., Kikuzawa, Y. P., Ng, C. S. L., Taira, D., Afiq-Rosli, L., Tan, K. S., and Chou, L. M. (2017). Egg Capsules and Veligers of the Corallivorous Muricid Gastropod *Drupella rugosa* (Born, 1778). Invertebrate Reproduction and Development, 61(3): 164 – 171.

Samsi, A. N., Asaf, R., Sahabuddin, S., Santi, A., and Wamnebo, M. I. (2017). Review: Gastropods as a Bioindicator and Biomonitoring Metal Pollution. Aquacultura Indonesiana, 18(1): 1 – 8.

Samson, J. E., Miller, L. A., Ray, D., Holzman, R., Shavit, U., and Khatri, S. (2019). A Novel Mechanism of Mixing by Pulsing Corals. Journal of Experimental Biology, 222(15); 1 – 13.

Samsuri, A. N., Kikuzawa, Y. P., Taira, D., Sam, S. Q., Sim, W. T., Ng, C. S. L., Afiq-Rosli, L., Wee, T. C. D., Ng, N. K., Toh, T. C., and Chou, L. M. (2018). The Effectiveness of *Trapezia cymodoce* in Defending its Host Coral *Pocillopora acuta* against Corallivorous *Drupella*. Marine Biology, 165: 1 – 8.

Sánchez-Hernández, J. (2020). Taxonomy-Based Differences in Feeding Guilds of Fish. Current Zoology, 66(1): 51 – 56.

Sanpanich, K., and Duangdee, T. (2015). The Species Diversity and Assessment of Marine Mollusks in Coral Reefs from Sattahip District, Chonburi Province, Thailand (pp. 111 – 122). Springer Science and Business Media, Singapore.

Sanpanich, K., and Duangdee, T. (2018). A Survey of Marine Mollusc Diversity in the Southern Mergui Archipelago, Myanmar. Phuket Marine Biological Center Research Bulletin, 75: 45 – 60.

Sanpanich, K., and Tan, S. K. (2016). Shell-Bearing Gastropod Molluscs of the Singapore Strait. The Raffles Bulletin of Zoology, 34: 528 – 538.

Saponari, L., Dehnert, I., Galli, P., and Montano, S. (2021). Assessing Population Collapse of *Drupella* spp. (Mollusca: Gastropoda) 2 Years after a Coral Bleaching Event in the Republic of Maldives. Hydrobiologia, 848(11): 2653 – 2666.

Schaefer, N., Mayer-Pinto, M., Johnston, E. L., and Dafforn, K. A. (2023). Understanding the Role of Microhabitats in Intertidal Rock Pools to Guide Future Eco-Engineering Designs. Marine Biology, 170(4): 1 – 11.

Scheffers, B. R., Edwards, D. P., Diesmos, A., Williams, S. E., and Evans, T. A. (2014). Microhabitats Reduce Animal's Exposure to Climate Extremes. Global Change Biology, 20(2): 495 – 503.

Schoepf, V., Herler, J., and Zuschin, M. (2010). Microhabitat Use and Prey Selection of the Coral-Feeding Snail *Drupella cornus* in the Northern Red Sea. Hydrobiologia, 641: 45 – 57.

Scott, C. M., Mehrotra, R., Hein, M. Y., Moerland, M. S., and Hoeksema, B. W. (2017). Population Dynamics of Corallivores (*Drupella* and *Acanthaster*) on Coral Reefs of Koh Tao, a Diving Destination in the Gulf of Thailand. Raffles Bulletin of Zoology, 65: 68 – 79.

Seinor, K. M., Smith, S. D. A., Logan, M., and Purcell, S. W. (2020). Biophysical Habitat Features Explain Colonization and Size Distribution of Introduced *Trochus* (Gastropoda). Frontiers in Marine Science, 7: 1 – 12.

Shafie, N. J., Anuar, H., David, G., Ahmad, A., and Abdullah, M. T. (2023). Bird Species Composition, Density and Feeding Guilds in Contrasting Lowland Dipterocarp Forests of Terengganu, Peninsular Malaysia. Tropical Ecology, 64(2): 238 – 248.

Shah, J. A., and Pandit, A. K. (2013). Application of Diversity Indices to Crustacean Community of Wular Lake, Kashmir Himalaya. International Journal of Biodiversity and Conservation, 5(6): 311 – 316.

Sharif, A. S. M., Islam, S., and Islam, M. (2017). Spatial and Temporal Environmental Variable Affect of the Lower Meghna River & its Estuary on Macrobenthic Fauna, Bangladesh. International Journal of Marine Science, 7(12): 102 – 113.

Shariful, F., Sedrati, M., Ariffin, E. H., Shubri, S. M., and Akhir, M. F. (2020). Impact of 2019 Tropical Storm (Pabuk) on Beach Morphology, Terengganu Coast (Malaysia). Journal of Coastal Research, S1: 346 – 350.

Shaver, E. C., Renzi, J. J., Bucher, M. G., and Silliman, B. R. (2020). Relationships between a Common Caribbean Corallivorous Snail and Protected Area Status, Coral Cover, and Predator Abundance. Scientific Reports, 10(1): 1 – 10.

Sheppard, C. (2021). Coral Reefs: A Natural History (pp.1 – 106). Princeton

University Press: United States

Shima, J. S., Phillips, N. E., and Osenberg, C. W. (2013). Consistent Deleterious Effects of Vermetid Gastropods on Coral Performance. Journal of Experimental Marine Biology and Ecology, 439: 1 – 6.

Shin, C. P., and Allmon, W. D. (2023). How We Study Cryptic Species and Their Biological Implications: A Case Study from Marine Shelled Gastropods. Ecology and Evolution, 13: 1 – 18.

Simmonds, S. E., Chou, V., Cheng, S. H., Rachmawati, R., Calumpong, H. P., Ngurah Mahardika, G., and Barber, P. H. (2018). Evidence of Host-Associated Divergence from Coral-Eating Snails (genus *Coralliophila*) in the Coral Triangle. Coral Reefs, 37: 355 – 371.

Simmonds, S. E., Fritts-Penniman, A. L., Cheng, S. H., Mahardika, G. N., and Barber, P. H. (2020). Genomic Signatures of Host-Associated Divergence and Adaptation in a Coral-Eating Snail, *Coralliophila violacea* (Kiener, 1836). Ecology and Evolution, 10: 1817 – 1837.

Sobha, T. R., Vibija, C. P., and Fahima, P. (2023). Coral Reef: A Hot Spot of Marine Biodiversity. Conservation and Sustainable Utilization of Bioresources (pp. 171 – 194). Springer Nature Singapore: Singapore.

Soekendarsi, E. (2019). Gastropods and Edible Macroalgae. Journal of Physics: Conference Series, 1341: 1 – 4.

Sonak, S. M. (2017). Molluscs and Their Shells. (pp. 1 – 22). Springer Nature, Switzerland.

Sosnowski, M. C., Weis, J. S., and Petrossian, G. A. (2020). Using Crime Script Analysis to Understand the Illegal Harvesting of Live Corals: Case Studies from Indonesia and Fiji. Journal of Contemporary Criminal Justice, 36(3): 384 – 402.

Speare, L., Klinges, J. G., Duke, W. C., Muller, E. M., and Thurber, R. L. V. (2023). Nutrient Enrichment Alters Gene Expression in 'Ca.' *Aquarickettsia rohweri,* Promoting Parasite Expansion and Horizontal Transmission. *BioRxiv*, 1 – 33.

Srivastava, A. K., and Singh, V. K. (2021). Feeding Behaviours in Gastropod Molluscs. Journal of Cell and Molecular Biology, 5: 1 – 6.

Stella, J. S., Wolfe, K., Roff, G., Rogers, A., Priest, M., Golbuu, Y., and Mumby, P. J.

(2022). Functional and Phylogenetic Responses of Motile Cryptofauna to Habitat Degradation. Journal of Animal Ecology, 91(11): 2203 – 2219.

Subhan, B., Arafat, D., Rahmawati, F., Dasmasela, Y. H., Royhan, Q. M., Madduppa, H., Santoso, B., and Prabowo, B. (2020). Coral Disease at Mansuar Island, Raja Ampat, Indonesia. IOP Conference Series: Earth and Environmental Science, 429: 1 – 10.

Sujarta, P., Mailissa, M. G., Keiluhu, H. J., Hadisusanto, S., and Yuliana, S. (2022). Community Distribution and Utilization of Gastropods in the Coastal Area of Liki Island, Sarmi District, Papua, Indonesia. Biodiversitas, 23: 5001 – 5011.

Sukawati, N. K. A., Restu, I. W., and Saraswati, S. A. (2018). Sebaran dan Struktur Komunitas Moluska di Pantai Mertasari Kota Denpasar, Provinsi Bali. Journal of Marine and Aquatic Sciences, 4(1): 78 – 85.

Sullivan-Stack, J., Ahmadia, G. N., Andradi-Brown, D. A., Barron, A., Brooks, C. M., Claudet, J., Costa, B. H. E., Field, L. C., Giakoumi, S., Gonçalves, E., Groulx, X., Harris, J., Jessen, S., Johnson, S. M., MacCarthy, J. M. C., Maricato, G., Morgan, L., Nalven, K. B., Nocito, E. S., Pike, E. P., Sala, E., Tardin, R., Villagomez, A., Wright, K., and Grorud-Colvert, K. (2024). Assessments of Expected MPA Outcomes Can Inform and Improve Biodiversity Conservation: Case Studies Using the MPA Guide. Marine Policy, 170: 1 – 12.

Sun, Q., and Zhang, S. (2014). A New Species of *Cerithium* (Gastropoda: Cerithiidae) from the South China Sea. Chinese Journal of Oceanology and Limnology, 32(5): 1118 – 1122.

Suyadi, S., Nugroho, D. A., Irawan, A., Pelasula, D., Ruli, F., Islami, M. M., Alik, R., Tala, J. D., Pay, L., Matuankotta, C., Leatemia, A. S., and Naroli I. (2021). Biodiversity in the Coastal Ecosystems of Small Islands and Its Conservation Status. IOP Conference Series: Earth and Environmental Science, 762: 1 – 12.

Syahrul, M., and Amri, K. (2022). Linkages between Coral Reef Conditions with the Distribution and Diversity of Megabenthic Fauna in the Waters of Barranglompo Island, Makassar City. Jurnal Ilmu Kelautan SPERMONDE, 8(2): 8 – 18.

Tan, C. J., Kang, D. R., and Liu, L. L. (2024). Distribution and Population Structure of Corallivorous *Drupella* Snails in the Coral Reefs of Kenting in Taiwan. Journal of Marine Science and Technology, 32(3): 280 – 287.

Tang, S., Hui, T. H., Ahmed, P. K., Nair, M. S., and Vaithilingam, S. (2022). Marine Protected Area in Southeast Asia: A Brief Look into the Current Landscape, Key Benefits, and Challenges. (pp. 1 – 59). Sunway University, Subang Jaya, Malaysia.

Taylor, J. D. (1968). Coral Reef and Associated Invertebrate Communities (Mainly Molluscan) around Mahe, Seychelles. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 254: 129 – 206.

Tebiary, L. A., Leiwakabessy, F., and Rumahlatu, D. (2022). Species Density and Morphometric Variation of Species Belonging to *Conus* (Gastropoda: Conidae) Genera in the Coastal Waters of Ambon Island, Indonesia. Biodiversitas, 23: 1664 – 1676.

Titlyanov, E. A., and Titlyanova, T. V. (2009). The Dynamics of the Restoration of Mechanical Damage to Colonies of the Scleractinian Coral *Porites lutea* Under Conditions of Competition with Algal Settlers for Substratum. Russian Journal of Marine Biology, 35: 230 – 235.

Titlyanov, E. A., and Titlyanova, T. V. (2020). Symbiotic Relationships between Microalgal Zooxanthellae and Reef-Building Coral Polyps in the Process of Autotrophic and Heterotrophic Nutrition. Russian Journal of Marine Biology, 46: 307 – 318.

Toda, T., Okashita, T., Maekawa, T., Alfian, B. A. A. K., Rajuddin, M. K. M., Nakajima, R., Chen, W., Takahashi, K. T., Othman, B. H. R., and Terazaki, M. (2007). Community Structures of Coral Reefs around Peninsular Malaysia. Journal of Oceanography, 63: 113 – 123.

Tsafack, N., Rebaudo, F., Wang, H., Nagy, D. D., Xie, Y., Wang, X., and Fattorini, S. (2019). Carabid Community Structure in Northern China Grassland Ecosystems: Effects of Local Habitat on Species Richness, Species Composition and Functional Diversity. PeerJ, 6: 1 – 26.

Tsang, H. L. (2017). The Roles of *Drupella* Corallivory in Shaping Coral Communities Under Stressful Hong Kong Marine Environment (Doctoral Dissertation).

Tsang, R. H. L., Chui, A. P. Y., Wong, K. T., and Ang Jr, P. (2018). Corallivory plays a limited role in the mortality of new coral recruits in Hong Kong marginal coral communities. Journal of Experimental Marine Biology and Ecology, 503: 100 – 108.

Tsang, R. H. L., and Ang, J. P. (2019). Resistance to Temperature Stress and *Drupella* corallivory may Promote the Dominance of *Platygyra acuta* in the Marginal Coral Communities in Hong Kong. Marine Environmental Research, 144: 20 – 27.

Uchmański, J., Opaliński, K. W., and Rau, K. (2018). Intraspecific Competition in an Island Environment: Variability and Dispersal of Terrestrial Snail *Helix aspersa aspersa* Müller, 1774 (Gastropoda: Helicidae). Acta Zoologica Bulgarica Supply, 12: 25 – 39.

Vian, L. W., Nilamani, N., Sharuiddin, S. F. F., Woo, S. P., Ilias, N., Yasin, Z., and Hwai, A. T. S. (2022). Diversity and Distribution of Molluscs (Gastropoda and Bivalvia) in the Seagrass Beds at Pulau Gazumbo, Penang, Malaysia. Journal of Survey in Fisheries Sciences, 9(1): 79 – 95.

Viehman, T. S., Reguero, B. G., Lenihan, H. S., Rosman, J. H., Storlazzi, C. D., Goergen, E. A., and Hench, J. L. (2023). Coral Restoration for Coastal Resilience: Integrating Ecology, Hydrodynamics, and Engineering at Multiple Scales. Ecosphere, 14(5): 1 – 19.

Voolstra, C. R., Peixoto, R. S., and Ferrier-Pagès, C. (2023). Mitigating the Ecological Collapse of Coral Reef Ecosystems: Effective Strategies to Preserve Coral Reef Ecosystems. EMBO Reports, 24(4): 1 – 7.

Wagner, D., Friedlander, A. M., Pyle, R. L., Brooks, C. M., Gjerde, K. M., and Wilhelm, T. A. (2020). Coral Reefs of the High Seas: Hidden Biodiversity Hotspots in Need of Protection. Frontiers in Marine Science, 7: 1 – 13.

Wang, H., Wang, G., and Gu, W. (2020). Macroalgal Blooms Caused by Marine Nutrient Changes Resulting from Human Activities. Journal of Applied Ecology, 57(4): 766 – 776.

Watz, J., & Nyqvist, D. (2022). Interspecific Competition Among Terrestrial Slugs. Journal of Molluscan Studies, 88(2): 1 – 5.

Wells, F. E., Sanpanich, K., Tan, S. K., and Duangdee, T. (2021). The Marine and Estuarine Molluscs of Thailand. (pp. 1 – 187). Lee Kong Chian Natural History Museum National University of Singapore, Singapore.

Woodhead, A. J., Hicks, C. C., Norström, A. V., Williams, G. J., and Graham, N. A. (2019). Coral Reef Ecosystem Services in the Anthropocene. Functional Ecology, 33(6): 1023 – 1034.

WoRMS (2021). World of Register Marine Species. Retrieved from http://www.marinespecies.org.

Worthington, D. G., and Fairweather, P. G. (1989). Shelter and Food: Interactions between *Turbo undulatum* (Archaeogastropoda: Turbinidae) and Coralline Algae on Rocky Seashores in New South Wales. Journal of Experimental Marine Biology and Ecology, 129(1): 61 – 79.

Wright, J. M., O'Connor, W. A., Parker, L. M., and Ross, P. M. (2018). Predation by the Endemic Whelk *Tenguella marginalba* (Blainville, 1832) on the Invasive Pacific Oyster *Crassostrea gigas* (Thunberg, 1793). Molluscan Research, 38(2): 130 – 136.

Yokochi, H. (2004). Predation Damage to Corals. (pp. 49 – 55). Ministry of the Environment and Japanese Coral Reef Society, Tokyo, Japan.

Young, C. S., and Gobler, C. J. (2020). Hypoxia and Acidification, Individually and in Combination, Disrupt Herbivory and Reduce Survivorship of the Gastropod, *Lacuna vincta*. Frontiers in Marine Science, 7: 1 – 17.

Yusuf, S., Jompa, J., Ahmad, M., Umar, W., and Limmon, G. V. (2019). Biogeography and Diversity of *Lobophyllia*, an Ornamental Coral Traded in the Coral Triangle. IOP Conference Series: Earth and Environmental Science, 253: 1 – 7.

Zahoor, I., and Mushtaq, A. (2023). Water Pollution from Agricultural Activities: A Critical Global Review. International Journal of Chemical and Biochemical. Sciences, 23(1): 164 – 176.

Zaidi, N., Douafer, L., and Hamdani, A. (2021). Diversity and Abundance of Terrestrial Gastropods in Skikda Region (North-East Algeria): Correlation with Soil Physicochemical Factors. Journal of Basic and Applied Zoology, 82: 1 – 10.

Zainuddin, S. N. H., Nie, L. J., Fahmi, A. D. M., Idris, I., and Baharuddin, N. (2024). Coral-Grazing Gastropods Diversity in Shallow Reefs, Pulau Redang Marine Park, Terengganu, Malaysia. AACL Bioflux, 17(3): 1026 – 1038.

Zakaria, M. H., Bujang, J. S., and Razak, F. R. A. (2003). Occurrence and Morphological Description of Seagrasses from Pulau Redang, Terengganu, Malaysia. Jurnal Teknologi, 38: 29 – 39.

Zakaria, N. Z. (2013). Ecology of Gastropods in Setiu Lagoon, Terengganu, Malaysia (Master Dissertation).

Zhang, F., Jia, X., Lin, Z., Jiang, Y., and Qu, M. (2024). The Outbreak of *Drupella* Snails and its Catastrophic Effects on Coral Reefs: A Comprehensive Review. Frontiers in Marine Science, 10: 1 – 12.

Zhang, H., Shin, P. K., and Cheung, S. G. (2016). Physiological Responses and Scope for Growth in a Marine Scavenging Gastropod, *Nassarius festivus* (Powys, 1835), are Affected by Salinity and Temperature but not by Ocean Acidification. ICES Journal of Marine Science, 73(3): 814 – 824.

Zvuloni, A., Armoza-Zvuloni, R., and Loya, Y. (2008). Structural Deformation of Branching Corals Associated with the Vermetid Gastropod *Dendropoma maxima*. Marine Ecology Progress Series, 363: 103 – 108.

APPENDICES

Appendix 1: Overall checklist of coral reef gastropods in all stations

No	Family	Genus	Species	PBD	PKS	PPH	PRD	PTG	PYB	PYK
1	Turbinidae	*Astralium*	*Astralium rhodostomum*	-	-	-	+	-	-	-
2	Cerithiidae	*Cerithium*	*Cerithium columna*	-	-	+	-	-	-	-
3	Cerithiidae	*Cerithium*	*Cerithium coralium*	-	-	-	-	+	-	-
4	Muricidae	*Coralliophila*	*Coralliophila violacea*	-	-	-	-	+	-	-
5	Muricidae	*Drupella*	*Drupella cornus*	+	-	+	-	+	+	+
6	Muricidae	*Drupella*	*Drupella rugosa*	+	+	+	+	+	+	+
7	Muricidae	*Morula*	*Morula spinosa*	+	+	+	+	-	-	+
8	Muricdae	*Arakawania*	*Arakawania ceylonica*	-	-	-	-	-	+	+
9	Muricdae	*Arakawania*	*Arakawania marginalba*	+	+	+	+	+	+	+

Appendix 2: Feeding guilds of coral reef gastropods

A) Percentage of feeding guilds among islands.

Feeding guilds (%)	PPH	PRD	PKS	PTG	PYB	PYK	PBD
Corallivorous	28.40	22.09	7.50	9.47	3.94	8.28	20.32
Carnivorous	35.14	29.73	9.73	2.16	3.24	15.68	4.32
Herbivorous	8.33	83.33	-	8.33	-	-	-

B) Percentage of feeding guilds within islands.

Stations	Corallivorous	Carnivorous	Herbivorous
PBD	14.63	1.14	-
PKS	5.40	2.56	-
PPH	20.45	9.23	0.14
PRD	15.91	7.81	1.4
PTG	6.82	0.57	0.14
PYB	2.84	0.85	-
PYK	5.97	4.12	-

BIODATA OF AUTHOR

The author, Siti Nur Hakimah Binti Zainuddin was born on 14th September 1997 at Kampung Setar Kanan, Marang, Terengganu. She is the eldest of her siblings. She went to Tabika Kemas Marang, Terengganu for her first education. Then, she went to Sekolah Kebangsaan Seberang Marang and Sekolah Kebangsaan Rhu Rendang for her primary school from January 2004 until September 2009. After UPSR, she was offered to a premier school, Sekolah Menengah Kebangsaan Tengku Lela Segara for her secondary education until 2014. Then, she further her studies in the pure science module (1-year programme) at Kolej Matrikulasi Pahang (KMPH). Being in love with a variety of life (plants, animals, fungi, and microorganisms) and environment, she then furthered her studies with a Bachelor of Applied Science (Biodiversity Conservation and Management) at Universiti Malaysia Terengganu (UMT), Terengganu, and successfully graduated with honours in November 2019. Shortly after graduating, she continued her studies for a Master of Science (Marine Ecology) (Research) at UMT.

Her master's research focuses on the Mollusca ecology, specifically on gastropods associated with the coral reef ecosystem in Terengganu marine protected islands, Malaysia. During her Master's study, she was actively involved in seminars, workshops, expeditions, and conferences. She was also involved in a few consultation projects including 'Post COVID-19 Marine Life Status at Marine Park Islands of Terengganu' and 'Coral Conservation and Restoration Towards Sustainable Ecosystem' funded by International Petroleum Corporation (IPC). She was also selected to participate in the International Coral Reef Seminar, involving researchers from Universiti Malaysia Terengganu and Heriot-Watt University.

International Coral Reef Seminar

Empowering Postgraduates Seminar

PUBLICATION

Zainuddin, S. N. H., Nie, L. J., Fahmi, A. D. M., Idris, I., and Baharuddin, N. (2024). Coral-grazing gastropods diversity in shallow reefs, Pulau Redang Marine Park, Terengganu, Malaysia. AACL Bioflux, 17(3): 1026 – 1038.

Coral-grazing gastropods diversity in shallow reefs, Pulau Redang Marine Park, Terengganu, Malaysia

[1]Siti N. H. Zainuddin, [1]Lee J. Nie, [1]Afiq D. M. Fahmi, [2]Izwandy Idris, [1]Nursalwa Baharuddin

[1] Faculty of Science and Marine Environment, Malaysia Terengganu University, Kuala Nerus, Terengganu, Malaysia; [2] South China Sea Repository & Reference Centre, Institute of Oceanography & Environment, Malaysia Terengganu University, Kuala Nerus, Terengganu, Malaysia. Corresponding author: N. Baharuddin, nursalwa@umt.edu.my

Abstract. The global deterioration of coral reefs has prompted research to comprehend the various impacts on coral's organisms as well as the interactions between reefs and their natural predators, coral grazing marine gastropods. However, the status of marine gastropods on Pulau Redang Marine Park is lacking. The study assessed marine gastropod diversity and shell morphometrics as indicators of the coral reef health ecosystem. SCUBA divers laid out a coral belt transect line of 50 m x 10 m at five sites. 177 individuals from four species of two families (Turbinidae and Muricidae; subclasses Vetigastropoda and Caenogastropoda) were collected at other locations. The highest number of individuals belonged to *Drupella rugosa* with 112 individuals, and the lowest number was *Astralium rhodostomum*. For the studied of marine snails, the Shannon index of diversity was H'=0.9 (<2) and the Simpson index of dominance was D=0.5 (<1). In addition, a high evenness, J', and equitability Ep were recorded at the sites of Pulau Redang. In terms of morphometrics, *A. rhodostomum* had the highest value of shell length (28.49±7.06 mm) and shell width (26.63±5.21 mm). No gastropods were found in Chagar Hutang and Mak Simpan due to coral destruction caused by the cyclonic Pabuk storm in early January 2019. Although it is a baseline, future research should also focus on parameters such as seawater temperature and coral bleaching towards effects on corallivorous gastropods and interaction between gastropods species.

Key Words: marine gastropods, recovery, islands, diversity test, morphometrics.

Introduction. Tropical coral reefs are diverse ecosystems that are home to around 830,000 marine species identified by scientists (Fisher et al 2015). Millions of people rely on this complex ecosystem for their livelihoods, cultures, and food production (Eddy et al 2018). The benefits provided by coral reefs can be categorized into two types: provisioning services, which include fisheries, cultural recreation, and tourism (Brander et al 2007), and regulating services, such as coastal protection, which have been extensively researched by scientists (Ferrario et al 2014). Coral reefs are not only beautiful ecosystems, but they also play a crucial role as biological engineers and keystone species. They create and maintain ideal conditions for the survival of a diverse range of animals and plants in the shallow coastal ecosystem (Gillis et al 2014).

Peninsular Malaysia is located on the Sunda Shelf and within the coral triangle region, the world's center of marine biodiversity with 627 species of corals recorded (Veron et al 2015). Malaysia's coral reefs are relatively shallow, and the climate is influenced by the monsoonal wind system, namely the northeast monsoon (Nov-Feb) and southwest monsoon (June-September) (Akhir 2012). Approximately 500 scleractinian coral species are distributed over 4,006 km^2 (Praveena et al 2012). Branching *Acropora* and massive *Porites* contribute with the highest percentage to the coral reef communities in Malaysia's marine ecosystem (Safuan et al 2020). Anthropogenic activities, such as destructive fishing, coral mining (Caras & Pasternak 2009), natural disturbances (e.g., extreme weather events), sedimentation (Fabricius et al 2005), and corallivory, pose threats to coral reef ecosystems (Rice et al 2019) and have caused destruction to coral reef communities on the East Coast islands of Peninsular Malaysia. Over 160 coral predators, or corallivores, are known to prey on coral reefs (Rotjan & Lewis 2008). These range from facultative consumers such as species from the Scaridae (parrotfish) (Turner 2020) and Cidaridae (sea urchins) (Glynn 2004) families to obligate predators such as those from the Chaetodontidae (butterflyfish) (Feary et al 2018), Acanthasteridae (crown-of-thorns starfish) (Pratchett et al 2017), and Muricidae (gastropods) families (Gautrand et al 2023).

Ectoparasitic corallivorous gastropods are organisms that cause significant damage to coral community, affecting its dynamics in different directions and at various densities (Mumby 2009). Their feeding behavior leads to a reduction in coral cover, which disrupts the ecosystem (Bruckner et al 2017). Corallivorous snails feed on coral reef soft tissue, which seriously hinders coral recovery (Kaullysing et al 2016). The first outbreak of corallivorous gastropods from the family Muricidae, specifically genus *Drupella*, was first recorded in the early 1980s in the coral reefs of Southern Japan (Moyer et al 1982). Since then, scientists have become increasingly aware of this issue because excessive density of corallivorous gastropods have a negative impact on coral cover (Bessey et al 2018). Previous studies indicate that most corallivorous gastropods primarily feed on scleractinian corals with small polyps, such as *Acropora*, *Montipora*, and *Pocillopora* (Al-Horani et al 2011). Among these, branching *Acropora* is the most preferred genus due to its complex coral structures and design. It provides a larger surface area, sufficient amount of living tissue to feed on, and a place to hide from predators, ocean currents, and waves (Bessey et al 2018). After removing the soft tissue, *Drupella* corallivorous snails usually lay their egg capsules on the bare coral's skeleton (Scott et al 2017). However, observations of the early life stages of snails are still minimal due to their cryptic behavior and small capsule size (Sam et al 2016). Corallivorous gastropods exhibit clustering behavior at different scales, ranging from a few individuals to three million individuals per square kilometer (Cumming 2009). This leads to population outbreaks that significantly impact the coral reef ecosystem (Schoepf et al 2010).

This study conducted a thorough analysis of the diversity, abundance, and shell characteristics of coral-grazing gastropod in Pulau Redang Marine Park, Malaysia. It serves as a valuable resource to enhance our understanding of mollusks, particularly corallivorous gastropods, in Malaysia. Additionally, it addresses knowledge gaps related to the potential threats these gastropods pose to the marine park.

Material and Method

Description of the study sites. The study was undertaken within Pulau Redang Marine Park (PRMP), situated approximately 24 nautical miles away from the Terengganu mainland. According to the Marine Park Malaysia Order of 1994, the waters encircling several islands in the archipelago were officially designated as part of PRMP (Mamat et al 2013). PRMP's eastern coast boasts white sandy beaches, while its western coast is characterized by rocky terrain adorned with diverse forest types (Mamat et al 2013). For this study, five distinct sites were meticulously chosen: Chagar Hutang (CH) to the north, Terumbu Kili (TK) to the south, Pulau Lima (PL) to the east, Pulau Kerengga Besar (KB) to the southeast, and Pasir Mak Simpan (MS) to the west (Figure 1). Sampling activities were carried out across these sites from the 16^{th} to the 18^{th} of July 2020.

Sampling method. Scuba divers conducted surveys along a 50 x 10 m transect within coral areas situated at depths ranging from 8 m to 12 m at each designated sampling site. Marine gastropods inhabiting these coral areas, specifically *Acropora* and *Pocillopora* colonies, were systematically collected along each transect, adhering to the protocols outlined by McClanahan (1997) and a preliminary survey. These methods were suitably adjusted to align with the unique characteristics of the study area. To document the presence or absence of both marine gastropods and their coral prey species, a series of underwater photographs were taken. The gastropods observed at the sites were meticulously gathered using extended forceps to ensure minimal disturbance to the coral colonies. Subsequently, these collected gastropods were placed within labelled plastic bags and stored within an ice chest. Before undergoing further morphometric analysis, they were then transferred to a freezer set at a temperature of 4°C.

Figure 1. Map of study sites; Chagar Hutang, Terumbu Kili, Pulau Lima, Pulau Kerengga Besar and Mak Simpan at Pulau Redang, Terengganu, Malaysia.

Gastropod identification and shell morphometrics. To elucidate the authentic external morphology, the shells of each gastropod were meticulously cleansed to eliminate any extraneous sand and attached symbionts. Species identification was pursued with the aid of available literature's identification keys and online resources, including World Register of Marine Species-WoRMS, Molluscabase and Hardy's Internet Guide to Marine Gastropods, along with key references by Wells et al (2021) and Abbott et al (1991). Quantitative shell morphometrics, encompassing measurements of shell length (mm) and width (mm), were obtained using an electronic vernier calliper with precision to two decimal places. Subsequently, each gastropod's wet weight was ascertained utilizing an electronic balance, with due attention to the instrument's brand and origin. For the determination of dry weight, gastropods were positioned on pre-weighed aluminium foil sheets of suitable dimensions, which were then weighed again employing an electronic balance. The samples were subsequently subjected to a drying process within an oven set at 65°C for approximately five days to determine the dry weight (g). To ensure consistency, the dry weight was recorded on day 3, 4, and 5. Following the drying process, the gastropods were transferred to labelled crucible jars. An ash oven was utilized to combust the gastropods at 450°C for a duration of 4 hours, after which they were allowed to cool. Subsequent to cooling, the gastropods were carefully removed from the crucible jars, and the shells were gently tapped to eliminate residual ash. The individual's ash-free dry weight (g) was subsequently gauged using an electronic balance. The Condition Index (CI) was calculated as the ratio of dry flesh weight (g) to dry shell weight (g).

Data analysis. Statistical analysis was conducted to evaluate the species diversity and richness within the studied area. The Shannon index was employed for calculating species diversity, which can be represented as:

$$H' = -\sum_{i=1}^{s} pi\ lnpi$$

Where:
H' - the value of the Shannon diversity index;
Pi=ni/N - the proportion of the (i) th species;
ni - the number of individuals within the species;
N - the total number of individuals across all species within the samples.

An increase in the index value signifies a rise in diversity. The Shannon index is categorized into three levels: low (H'<2), moderate (2<H'<4), and high (H'>4) (Odum & Barret 2004).

The Simpson index, often used to quantify habitat biodiversity, assesses the likelihood of randomly selecting two individuals belonging to different species from an infinitely large community (Simpson 1949). The Simpson diversity index (*D*) is calculated as follows:

$$D=1-\sum(Pi)^2$$

When (D) reaches 1, it signifies high diversity, while a value of 0 signifies low biodiversity.

The Margalef index (Ma) and the Menhinck index (Me) were applied to determine species and abundance, as outlined by Hammer et al (2001):

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

$$Me=s/\sqrt{N}$$

Where:
s - the number of distinct species within the sample;
N - the total count of individual organisms.

The Margalef index indicates the number of species per specified area or unit. The Margalef and Menhinick indices are significantly influenced by the sampling effort and provide valuable insights into biological diversity (Magurran 2021).

The organism species evenness was assessed using the Evenness index (J') and Equitability index (Ep). The homogeneity or pattern distribution of species was determined as follows:

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

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

Where:
H' - the Shannon diversity index;
S - the number of species.

A value of 1 indicates complete evenness, whereas a value of 0 suggests no evenness. The analyses were executed using PAST (Paleontological Statistics version 32.3.3). Additionally, the Frequency of Incidence (FoI) was estimated following the methodology outlined by Rahmawati et al (2015), employing the equation:

$$FoI=Ni.St/\ N.St \times 100\%$$

Where:
Ni.St - the total number of locations or study sites;
N.St - the count of sampling locations.

Results. A total of 177 individual marine gastropods, encompassing four distinct species, were collected from three different locations on Pulau Redang: Pulau Kerengga Besar (KB), Pulau Lima (PL), and Terumbu Kili (TK). These gastropods belong to two subclasses, Vetigastropoda and Caenogastropoda, representing two families, Turbinidae and Muricidae. Among the four species, namely *Astralium rhodostomum, Drupella rugosa, Morula spinosa*, and *Tenguella marginalba*, all were recorded in PL, while KB and TK had three species each, excluding *A. rhodostomum* (Figure 2, Table 1). *D. rugosa* accounted for the highest number of individuals, with a count of 112 collected from the three sites (KB, PL, and TK). The second most prevalent species was *T. marginalba* with 43 individuals, whereas *M. spinosa* and *A. rhodostomum* were represented by 12 and 10 individuals, respectively (Table 1, Figure 2). TK and KB exhibited a greater total number of individuals, with 94 and 51 respectively, as compared to PL, where the total count was lowest at 32 individuals. The Frequency of Incidence (FoI) was mainly contributed by *D. rugosa*, *M. spinosa,* and *T. marginalba,* collectively accounting for 60% of occurrences across all three sites. Conversely, *A. rhodostomum* had the lowest FoI at 20%, exclusively found in PL (Table 1). Notably, no gastropods were found at the other two study sites, Chagar Hutang and Pasir Mak Simpan.

Despite being the least common species on Pulau Redang, *A. rhodostomum* (Turbinidae) exhibited the longest and widest shell dimensions, with an average shell length of 29 mm and width of 26 mm. In contrast, *M. spinosa* (Muricidae) displayed the shortest and narrowest shells, with an average length and width of 16 mm and 11 mm, respectively (Table 2). This trend is reflected in the wet and dry weight as well, where *A. rhodostomum* had the heaviest average wet and dry weights at 10 g and 9 g, while *M. spinosa* were the lightest, at 1 g and 0.9 g (Table 2). The Condition Index remained similar across all recorded species, ranging from 1.07 to 1.12 (Table 2).

The Shannon diversity index (H') revealed low diversity at PL, KB, and TK, with values of 1.237, 0.724, and 0.845, respectively. This pattern was consistent with the Simpson index, which exhibited values below one for all study sites, indicating low dominance. However, considering relative abundance, the Margalef (*Ma*) and Menhinick (*Me*) indices were higher in PL (Ma=0.866, Me=0.707) and KB (Ma=1.007, Me=0.687), followed by TK (Ma=0.440, Me=0.309) (Table 3). In terms of evenness and equitability, both PL and TK demonstrated values closest to one, indicating high homogeneity (PL: J'=0.861, Ep=0.892; TK: J'=0.776, Ep=0.769). In contrast, KB exhibited lower values (J'=0.413, Ep=0.450), suggesting a more naturally varied distribution.

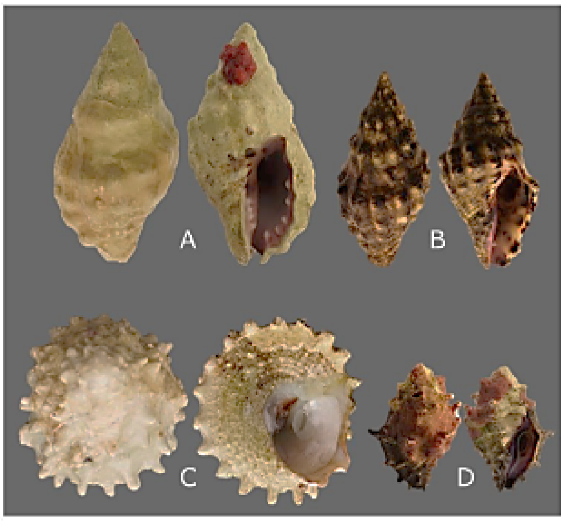

Figure 2. Apertural and abapertural view of corallivorous gastropods at Pulau Redang. (A) *Drupella rugosa*, 30 mm; (B) *Tenguella marginalba*, 24 mm; (C) *Astralium rhodostomum*, 22 mm; (D) *Morula spinosa*, 15 mm.

Table 1
Abundance of corallivorous gastropods found in all different sites according to subclasses according to subclass, family and species in Pulau Redang

Subclass	*Family*	*Species*	*Sites* *KB*	*PL*	*TK*	*CH*	*MS*	*Total ind.(n)*	*FoI (%)*
			No. of individuals						
Vetigastropoda	Turbinidae	*Astralium rhodostomum*	-	10	-	-	-	10	20
Caenogastropoda	Muricidae	*Drupella rugosa*	41	14	57	-	-	112	60
		Morula spinosa	1	5	6	-	-	12	60
		Tenguella marginalba	9	3	31	-	-	43	60
Total individual(s)			51	32	94	-	-	177	
Total species			3	4	3	-	-	5	

KB=Pulau Kerengga Besar, PL=Pulau Lima, TK=Terumbu Kili, CH=Chagar Hutang, MS=Mak Simpan. The total number of individuals (n) and Frequency of Incidence (*FoI*) contributed by each species;'- 'indicates absence.

Table 2
Shell morphometrics; shell length (mm), shell width (mm), aperture length (mm), aperture width (mm), wet weight (g), dry weight (g) and Condition Index of corallivorous gastropods following species and sample size (n)

Species	*Shell* *Length ± s.d. (n)*	*Width ± s.d. (n)*	*Weight* *Wet weight ± s.d (n)*	*Dry weight ± s.d (n)*	*Condition index*
Astralium rhodostomum	28.49±7.06 (10)	25.63±5.21 (10)	10.11±6.66 (10)	9.23±6.14 (10)	1.10±0.06 (10)
Drupella rugosa	28.00±2.25 (81)	15.09±1.31 (81)	3.81±0.84 (81)	3.71±0.73 (81)	1.12±0.19 (81)
Morula spinosa	15.15±4.14 (12)	10.99±3.64 (12)	1.03±0.61 (12)	0.93±0.56 (12)	1.07±0.03 (12)
Tenguella marginalba	17.09± 6.59 (43)	9.80±3.77 (43)	1.12±1.22 (43)	1.08±1.17 (43)	1.10±0.06 (43)

Table 3
Ecological indices of corallivorous gastropods in Pulau Kerengga Besar (KB), Pulau Lima (PL) and Terumbu Kili (TK)

Sites	*Indices* *Shannon*	*Simpson*	*Margalef*	*Menhinick*	*Evenness*	*Equitability*
	H'	*D*	*Ma*	*Me*	*J'*	*Ep*
KB	0.724	0.372	1.007	0.687	0.413	0.450
PL	1.237	0.680	0.866	0.707	0.861	0.892
TK	0.845	0.520	0.440	0.309	0.776	0.769

Discussion. The study identified *D. rugosa* as the most abundant species, with a total of 112 individuals collected, constituting a significant proportion of the overall sample. This species is known for its widespread distribution and its frequent presence on shallow reefs (Cumming 2009). However, a study conducted in 2016 documented a considerably higher count of 401 individuals across similar study sites on Pulau Redang Marine Park, including Chagar Hutang (CH) and Mak Simpan (MK) (Baharuddin et al 2017). The recent decline in the abundance of *D. rugosa* observed in this study, accounting for nearly a quarter reduction, signifies a noteworthy shift from the 2016 record. Malaysia, positioned below the 50° latitude and proximate to the equator, is generally safeguarded from direct tropical storms (Gray 1868). This is attributed to the weak Coriolis force near the equator, which impedes the rotation of air masses (Gray 1968; Chang et al 2003; Zuki & Lupo 2008). Nevertheless, an exception occurred in early January 2019 when the Pabuk storm emerged in the South China Sea and the Malaysian Peninsula, imparting a post-effect impact on Terengganu (Shariful et al 2020; Mohamad Basir et al 2022). Tropical storms are recognized as one of the most formidable physical disruptors to coral reefs (Lugo-Fernández et al 2004; Hongo 2018). The intense winds generated by storms like Pabuk inflict extensive damage on coral reefs, including the breakage of branching corals, dislodgment and removal of large colonies, and sediment deposition, culminating in coral mortality (Beeden et al 2015; Safuan et al 2020). This scenario has particularly impacted *D. rugosa,* which predominantly preys on branching corals. The observed decline in their numbers is a likely consequence of the depletion of food and shelter resources following the disturbance caused by the Pabuk tropical storm on the coral reef ecosystem. In addition, the aftermath of such disasters can trigger intraspecific competition among *D. rugosa* adults for limited resources. In this context, the dominance of adult individuals over available food and space sources may lead to increased mortality among juveniles and intermediates. It is notable that *D. rugosa* typically deposits its egg capsules on exposed coral skeletons (Sam et al 2017). However, the impact of the disaster has likely disrupted this reproductive behavior, as the altered environment resulting from the storm may not be conducive for adult *D. rugosa* to carry out this process during their spawning months. With their habitat severely compromised, a study conducted by Saponari et al (2021) echoes this concern, suggesting that the reduction in coral reef presence coupled with heightened competition from algae could result in limited space for egg deposition. Consequently, this disturbance-driven reduction in reproductive success could contribute to the observed decline in the population of *D. rugosa.*

T. marginalba, the second most prevalent species encountered on Pulau Redang, exhibited its highest population at Terumbu Kili (TK), amounting to 31 individuals. This species stands out due to its distinctive characteristics, particularly its high-spired shells that offer protection against adverse conditions (Baharuddin et al 2019). *T. marginalba* is often observed along rocky edges and within crevices (Coulson et al 2011). Its presence spans intertidal zones and various depths within tropical and subtropical oceans, encompassing environments such as coral reefs (Cahyadi et al 2021). The distribution of this genus is notably influenced by factors including wave exposure, the abundance of competitors, and the availability of food resources (Coulson et al 2011). *T. marginalba* is recognized as a carnivorous gastropod, preying on barnacles, limpets, and oysters (Wright et al 2018). This predation behavior aligns with its membership in the Muricidae family, indicating adaptation to its prey consumption capacity.

M. spinosa, on the other hand, predominantly feeds on carrion, polychaetes, and small mollusks, similarly to the dietary preferences of other muricid gastropod species (Barco et al 2010). While the initial documentation of *M. spinosa* feeding on coral reefs originated from Japan, this species is more commonly regarded as a coral scavenger than a corallivore due to its feeding habits (Yokochi 2004). While *M. spinosa* does exist within Pulau Redang, its population and distribution do not solely rely on the coral reef community (Moerland et al 2016). This stems from the fact that the species does not exclusively rely on coral reef consumption, showcasing an ability to exploit alternative prey sources (Titlyanov & Titlyanova 2009). *M. spinosa* are recognized as carnivorous gastropods inhabiting the surfaces of coral reefs, where they also prey on small herbivorous gastropods (Soekendarsi 2019). *Morula* genus frequently engaged in feeding behaviors that involve drilling into sedentary or semi-mobile prey with the prey size often smaller than the predator (Taylor 1976).

A. rhodostomum from Turbinidae family are conspicuous herbivorous gastropods that are commonly found across intertidal and subtidal reefs (Worthington & Fairweather 1989). The population and size distribution of turbinid gastropods on intertidal reefs undergo alterations across environmental gradients that are associated with changes in elevation (Worthington & Fairweather 1989; Bruton et al 1991). In Pulau Redang, species such as *A. rhodostomum* exhibit longer shell lengths compared to other marine reef gastropods, likely due to their cone-shaped shells that enhance their survival in harsh environmental conditions (Chapman 1997). The notably high values of wet weight and dry weight in *A. rhodostomum* suggest that the species' reproductive cycle is supported by a plentiful availability of food and nutrients (Li et al 2011). Being a common coral reef-associated gastropod, *A. rhodostomum* plays a vital role as an algae grazer on coral reef surfaces (Meyer et al 2005). This may be attributed to the higher percentage of algae on coral reef surfaces in Pulau Lima (PL) in comparison to other sites, despite a reduction in algae coverage in Pulau Redang following the Pabuk storm aftermath (Lee et al 2020).

The Condition Index (CI) serves as a valuable tool for evaluating various ecophysiological aspects such as reproduction, growth, mortality, parasitic infection, and secretion, under specific environmental conditions to monitor the health of organisms (Mercado-Silva 2005; Mladineo et al 2007). *D. rugosa* was found to fall within the 'thin' fitness category, indicating a resting gonad undergoing the gametogenesis phase (Rahim et al 2012). In contrast, *M. spinosa* exhibited the lowest condition index, reflecting a significant reduction in tissue weight and declining protein and lipid levels during the spawning season (Sahin et al 2006). The ecological indices derived from this study suggest that the diversity of marine snails within shallow coral reefs of Pulau Redang is relatively low. The Shannon index (H') value can be interpreted according to the classification proposed by Wilhm & Dorris (1996). A value below 1 indicates significant pollution, a value between 1.0 and 3.0 suggests moderate pollution, while a value exceeding 3.0 represents a non-polluted environment. Based on this index, Pulau Redang is categorized as experiencing moderate pollution. The analysis of diversity could be influenced by natural physical disturbances such as the Pabuk storm, which caused damages leading to subsequent declines in both the percentage and population of coral reefs in Pulau Redang (Lee et al 2020). However, at both Pulau Lima and Terumbu Kili in 2020, the indices of Evenness (J') and Equitability (Ep) demonstrated a high level of species evenness. Gastropods from the Muricidae family have been observed to inhabit a wide range of coastal and marine habitats (Radwin & D'Atilio 1976; Apte 1998; Mills et al 2007), including deep-sea environments (Egorov 1993), rocky tide pools (Yamamoto 1997), oceanic coral reefs (Boucher 1986), and various latitudinal regions (Bouchet et al 2002). Muricidae gastropods also exhibit a tendency to aggregate and cluster together, conserving water and body moisture to prevent dehydration (Zhang et al 2016). These behavioral traits aid these murex snails in adapting and successfully surviving in challenging environments (Baharuddin et al 2018). Despite a decline in the number of *M. spinosa* individuals recorded in Pulau Redang, the species remains present across all three sites, with a Frequency of Incidence (FoI) of 60%. This finding is supported by their smaller body size, which enables effective concealment in narrow spaces, enhancing their ability to find shelter in adverse challenging environmental conditions (Mohammad Basir et al 2022). Nevertheless, the distribution of *M. spinosa* remains constrained by specific environmental factors, including wave exposure, the presence of predators, scarcity of food sources, and fluctuations in both air and sea temperatures (Kumbhar & Rivonker 2012).

The limited scientific information on the status of marine gastropods within shallow coral reefs in Pulau Redang poses constraints on both current and future coral reef conservation and management efforts. Consequently, conducting additional research in the future is of paramount importance to attain a profound understanding of the roles of marine gastropods, especially corallivorous gastropods, during phases of coral mortality and recovery in Pulau Redang.

Conclusions. The diversity of coral-grazing gastropods in Pulau Redang is low, with Shannon-Wiener index values below 2. *D. rugosa*, a common corallivore, and *A. rhodostomum*, which has the largest shell size, are notable species. The abundance of *D. rugosa* decreased after the Pabuk storm in 2020, which caused significant coral damage. This study provides essential data on marine gastropods in Pulau Redang, helping to create a comprehensive list of corallivorous gastropods. Future research should also examine the effects of seawater temperature, coral bleaching, and interactions between gastropod species. This research is crucial for monitoring and preserving coral reef health.

Acknowledgements. This study was funded and supported by the Department of Fisheries Malaysia under 'Mini-Expedition on the Marine Life of Terengganu Marine Park: A Post Covid 19 Study' led by Professor Zainudin Bachok. The authors would like to thank Mr. Syed Ahmad Rizal Tuan Nek for providing the Canon DSLR camera and his photography skills.

Conflict of interest. The authors declare no conflict of interest.

References

Abbott R. T., 1991 Seashells of Southeast Asia. Graham Brash, Singapore, 145 p.

Akhir M. M., 2012 Surface circulation and temperature distribution of southern South China Sea from global ocean model (OCCAM). Sains Malaysiana 41(6):701-714.

Al-Horani F. A., Hamdi M., Al-Rousan S. A., 2011 Prey selection and feeding rates of *Drupella cornus* (Gastropoda: Muricidae) on corals from the Jordanian coast of the Gulf of Aqaba, Red Sea. Jordan Journal of Biological Sciences 147(622):1-8.

Apte D., 1998 The book of Indian shells. Bombay Natural History Society, Oxford University Press, 187 p.

Baharuddin N., Idris I., Zulkifli S. Z., 2017 Population structure using shell morphometric and carbonate growth of corallivorous gastropods *Drupella rugosa* in Pulau Redang. Technical Report, pp. 120-126.

Baharuddin N., Basri N. B., Syawal N. H., 2018 Marine gastropods (Gastropoda: Mollusca) diversity and distribution on intertidal rocky shores of Terengganu, Peninsular Malaysia. AACL Bioflux 11(4):1144-1154.

Baharuddin N., Basir N. H. M., Zainuddin S. N. H., 2019 Tropical intertidal gastropods: Insights on diversity, abundance, distribution and shell morphometrics of Pulau Bidong, Malaysia. AACL Bioflux 12(4):1375-1387.

Barco A., Claremont M., Reid D. G., Houart R., Bouchet P., Williams S. T., Oliverio M., 2010 A molecular phylogenetic framework for the Muricidae, a diverse family of carnivorous gastropods. Molecular Phylogenetics and Evolution 56(3):1025-1039.

Beeden R., Maynard J., Puotinen M., Marshall P., Dryden J., Goldberg J., Williams G., 2015 Impacts and recovery from severe tropical cyclone Yasi on the Great Barrier Reef. PloS one 10(4):121-272.

Bessey C., Babcock R. C., Thomson D. P., Haywood M. D. E., 2018 Outbreak densities of the coral predator Drupella in relation to in situ Acropora growth rates on Ningaloo Reef, Western Australia. Coral Reefs 37(4):985-993.

Boucher L. M., 1986 Coral predation by muricid gastropods of the genus *Drupella* at Enewetak, Marshall Islands. Bulletin of Marine Science 38(1):9-11.

Bouchet P., Lozouet P., Maestrati P., Heros V., 2002 Assessing the magnitude of species richness in tropical marine environments: exceptionally high numbers of molluscs at a New Caledonia site. Biological Journal of the Linnean Society 75(4):421-436.

Brander L. M., Van Beukering P., Cesar H. S., 2007 The recreational value of coral reefs: a meta-analysis. Ecological Economics 63(1):209-218.

Bruckner A. W., Coward G., Bimson K., Rattanawongwan T., 2017 Predation by feeding aggregations of *Drupella* spp. inhibits the recovery of reefs damaged by a mass bleaching event. Coral Reefs 36(4):1181-1187.

Bruton J., Baird D., Coetzee P. S., 1991 Population structure and yield-per-recruit analysis of the giant periwinkle Turbo sarmaticus in the Cape St Francis region, South Africa. South African Journal of Marine Science 11(1):345-356.

Cahyadi G. A. B. Y. P., Pinasti R., Salwa A., Devi M. A., Fajriana L. R., Qudsiyati N., Calista P., Eprilurahman R., 2021 Biodiversity of gastropods in intertidal zone of Krakal Beach, Gunungkidul, Yogyakarta. Nusantara Science and Technology Proceedings, pp. 16-24.

Caras T., Pasternak Z., 2009 Long-term environmental impact of coral mining at the Wakatobi marine park, Indonesia. Ocean & Coastal Management 52(10):539-544.
Chang C. P., Liu C. H., Kuo H. C., 2003 Typhoon Vamei: An equatorial tropical cyclone formation. Geophysical Research Letters 30(3):1-4.
Chapman M. G., 1997 Relationships between shell shape, water reserves, survival and growth of high shore littorinids under experimental conditions in New South Wales, Australia. Journal of Molluscan Studies 63:511-529.
Coulson L. A., Perrin C., Roberts D. G., Minchinton T. E., Ayre D. J., 2011 Can limited dispersal or biotic interaction explain the declining abundance of the whelk, *Morula marginalba*, at the edge of its range? Biological Journal of the Linnean Society 103(4):849-862.
Cumming R. L., 2009 Case study: impact of *Drupella* spp. on reef-building corals of the Great Barrier Reef. Great Barrier Reef Marine Park Authority, Townsville, 97 p.
Eddy T. D., Cheung W. W. L., Bruno J. F., 2018 Historical baselines of coral cover on tropical reefs as estimated by expert opinion. Peer Journal 6:e4308.
Egorov R. V., 1993 Trophoninae (Muricidae) of Russian and adjacent waters. Ruthenica Supplement 1:1-48.
Fabricius K., De'ath G., McCook L., Turak E., Williams D. M., 2005 Changes in algal, coral and fish assemblages along water quality gradients on the inshore Great Barrier Reef. Marine Pollution Bulletin 51(1-4):384-398.
Feary D. A., Bauman A. G., Guest J., Hoey A. S., 2018 Trophic plasticity in an obligate corallivorous butterflyfish. Marine Ecology Progress Series 605:165-171.
Ferrario F., Beck M. W., Storlazzi C. D., Micheli F., Shepard C. C., Airoldi L., 2014 The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. Nature Communications 5(1):1-9.
Fisher R., O'Leary R. A., Low-Choy S., Mengersen K., Knowlton N., Brainard R. E., Caley M. J., 2015 Species richness on coral reefs and the pursuit of convergent global estimates. Current Biology 25(4):500-505.
Gautrand L., Gairin E., Sowinski J., Sowinski L., Krimou S., Trotier M., Lecchini D., 2023 High densities, rapid infestation and high feeding rates of corallivore gastropods on corals in Bora-Bora Island, French Polynesia. Regional Studies in Marine Science 66:103125.
Glynn P. W., 2004 High complexity food webs in low-diversity Eastern Pacific reef–coral communities. Ecosystems 7:358-367.
Gillis L. G., Bouma T. J., Jones C. G., Van Katwijk M. M., Nagelkerken I., Jeuken C. J. L., Ziegler A. D., 2014 Potential for landscape-scale positive interactions among tropical marine ecosystems. Marine Ecology Progress Series 503:289-303.
Gray W. M., 1968 Global view of the origin of tropical disturbances and storms. Monthly Weather Review 96(10):669-700.
Hammer Ø., Harper D. A. T., Ryan P. D., 2001 Paleontological statistics software: package for education and data analysis. Palaeontologia Electronica 4(1):1-9.
Hongo C., 2018 The hydrodynamic impacts of tropical cyclones on coral reefs of Japan: Key points and future perspectives. Coral Reef Studies of Japan, pp. 163-173.
Kaullysing D., Gopeechund A., Mattan-Moorgawa S., Taleb-Hossenkhan N., Kulkarni B., Bhagooli R., 2016 Increased density of the corallivore *Drupella cornus* on Acropora muricata colonies overgrown by *Padina boryana*. Proceedings of the 13th International Coral Reef Symposium, Honolulu, pp. 288-304.
Kumbhar J. V., Rivonker C. U., 2012 A new record of Morula anaxares with a description of the radula of three other species from Goa, Central West Coast of India (Gastropoda: Muricidae). Turkish Journal of Fisheries and Aquatic Sciences 12(1).
Lee J. N., Norizam M. M., Yusuf Y., 2020 Coral reefs health: View from benthic and fish populations. In: Post COVID-19 marine life status at marine parks islands of Terengganu report. Bachok Z., Nor A. B. M., Repin I. M. (eds), Department of Fisheries Malaysia, pp. 57-66.
Li Q., Yang L., Ke Q., Kong L., 2011 Gametogenic cycle and biochemical composition of the clam *Mactra chinensis* (Mollusca: Bivalvia): Implications for aquaculture and wild stock management. Marine Biology Research 7(4):407-415.

Lugo-Fernández A., Roberts H. H., Wiseman Jr W. J., 2004 Currents, water levels, and mass transport over a modern Caribbean coral reef: Tague Reef, St. Croix, USVI. Continental Shelf Research 24(17):1989-2009.

Magurran A. E., 2021 Measuring biological diversity. Current Biology 31(19):1174-1177.

Mamat M. P., Yacob M. R., Radam A., Ghani A. N. A., Fui L. H., 2013 Willingness to pay for protecting natural environments in Pulau Redang Marine Park, Malaysia. African Journal of Business Management 7(25):2420-2426.

McClanahan T. R., 1997 Dynamics of Drupella cornus population on Kenyan Coral Reefs. Proceedings of the 8th International Coral Reef Symposium 1:633–638.

Mercado-Silva N., 2005 Condition index of the eastern oyster, *Crassostrea virginica* (Gmelin, 1791) in Sapelo Island Georgia—effects of site, position on bed and pea crab parasitism. Journal of Shellfish Research 24(1):121-126.

Meyer C. P., Geller J. B., Paulay G., 2005 Fine scale endemism on coral reefs: archipelagic differentiation in turbinid gastropods. Evolution 59(1):113-125.

Mills S. W., Mullineaux L. S., Tyler P. A., 2007 Habitat associations in gastropod species at East Pacific Rise hydrothermal vents (9°50'N). The Biological Bulletin 212:185–194.

Mladineo I., Peharda M., Orhanović S., Bolotin J., Pavela-Vrančić M., Treursić B., 2007 The reproductive cycle, condition index and biochemical composition of the horse-bearded mussel Modiolus barbatus. Helgoland Marine Research 61(3):183-192.

Moerland M. S., Scott C. M., Hoeksema B. W., 2016 Prey selection of corallivorous muricids at Koh Tao (Gulf of Thailand) four years after a major coral bleaching event. Contributions to Zoology 85(3):291-309.

Mohamad Basir N. H., Baharuddin N., Ahmad A., 2022 Impact of tropical storm Pabuk on intertidal gastropods in Bidong Island, Malaysia. Bidong Island, Geography of the Physical Environment, pp. 119-128.

Moyer J. T., Emerson W. K., Ross M., 1982 Massive destruction of scleractinian corals by the muricid gastropod, Drupella, in Japan and the Philippines. Nautilus 96:69-82.

Mumby P. J., 2009 Phase shifts and the stability of macroalgal communities on Carribean coral reef. Coral Reefs 28(3):761-773.

Odum E. P., Barret G. W., 2004 Fundamentals of ecology. Thomson Brooks Cole Publishing, Belmont, USA, 624 p.

Pratchett M. S., Caballes C. F., Wilmes J. C., Matthews S., Mellin C., Sweatman H., Uthicke S., 2017 Thirty years of research on crown-of-thorns starfish (1986–2016): scientific advances and emerging opportunities. Diversity 9(4):41.

Praveena S. M., Siraj S. S., Aris A. Z., 2012 Coral reefs studies and threats in Malaysia: a mini review. Reviews in Environmental Science and Biotechnology 11:27-39.

Radwin G. E., D'Atillio A., 1976 Murex shells of the world: an illustrated guide to the Muricidae. Stanford University Press, Stanford.

Rahmawati R., Sarong M. A., Muchlisin Z. A., Sugianto S., 2015 Diversity of gastropods in mangrove ecosystem of western coast of Aceh Besar District, Indonesia. AACL Bioflux 8(3):265-271.

Rahim A. A., Idris M. H., Kamal A. H. M., Wong S. K., Arshad A., 2012 Analysis of condition index in *Polymesoda expansa* (Mousson 1849). Pakistan Journal of Biological Sciences 15(13):629–634.

Rice M. M., Ezzat L., Burkepile D. E., 2019 Corallivory in the Anthropocene: interactive effects of anthropogenic stressors and corallivory on coral reefs. Frontiers in Marine Science 5:525.

Rotjan R. D., Lewis S. M., 2008 Impact of coral predators on tropical reefs. Marine Ecology Progress Series 367:73-91.

Safuan C. D. M., Roseli N. H., Bachok Z., Akhir M. F., Xia C., Qiao F., 2020 First record of tropical storm (Pabuk-January 2019) damage on shallow water reef in Pulau Bidong, south of South China Sea. Regional Studies in Marine Science 35:101216.

Sahin C., Düzgüneş E., Okumuş İ., 2006 Seasonal variations in condition index and gonadal development of the introduced blood cockle *Anadara inaequivalvis* (Bruguiere, 1789) in the southeastern Black Sea coast. Turkish Journal of Fisheries and Aquatic Sciences 6(2):155-163.

Sam S. Q., Kikuzawa Y. P., Taira D., Ng C. S. L., Toh T. C., Chou L. M., 2016 First and observation of Drupella rugosa egg capsules on scleractinian coral *Pocillopora damicornis*. Bulletin of Marine Science 92(3):353-354.
Sam S. Q., Toh T. C., Kikuzawa Y. P., Ng C. S. L., Taira D., Afiq-Rosli L., Chou L. M., 2017 Egg capsules and veligers of the corallivorous muricid *gastropod Drupella rugosa* (Born, 1778). Invertebrate Reproduction & Development 61(3):164-171.
Saponari L., Dehnert I., Galli P., Montano S., 2021 Assessing population collapse of *Drupella* spp. (Mollusca: Gastropoda) 2 years after a coral bleaching event in the Republic of Maldives. Hydrobiologia 848(11):2653-2666.
Schoepf V., Herler J., Zuschin M., 2010 Microhabitat use and prey selection of the coral-feeding snail *Drupella cornus* in the northern Red Sea. Hydrobiologia 641(1):45-57.
Scott C. M., Mehrotra R., Hein M. Y., Moerland M. S., Hoeksema B. W., 2017 Population dynamics of corallivores (*Drupella* and *Acanthaster*) on coral reefs of Koh Tao, a diving destination in the Gulf of Thailand. Raffles Bulletin of Zoology 65:68-79.
Shariful F., Sedrati M., Ariffin E. H., Shubri S. M., Akhir M. F., 2020 Impact of 2019 tropical storm (Pabuk) on beach morphology, Terengganu Coast (Malaysia). Journal of Coastal Research 95(SI):346-350.
Simpson E. H., 1949 Measurement of diversity. Nature 163:688
Soekendarsi E., 2019 Gastropods and edible macroalgae. Journal Physics Conference Series 1341(2):022018.
Taylor J. D., 1976 Habitats, abundance and diets of muricacean gastropods at Aldabra Atoll. Zoological Journal of the Linnean Society 59(2):155-193.
Titlyanov E. A., Titlyanova T. V., 2009 The dynamics of the restoration of mechanical damage to colonies of the scleractinian coral Porites lutea under conditions of competition with algal settlers for substratum. Russian Journal of Marine Biology 35:230-235.
Turner A., 2020 Understanding the distribution of grazing scars and its relationship to grazer, coral, and algal densities. BSc Thesis, pp. 4-20.
Veron J., Stafford-Smith M., DeVantier L., Turak E., 2015 Overview of distribution patterns of zooxanthellate Scleractinia. Frontiers in Marine Science 81(1):1-19.
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.
Wells F. E., Sanpanich K., Tan S. K., Duangdee T., 2021 The marine and estuarine molluscs of Thailand. Lee Kong Chian Natural History Museum, Singapore, 195 p.
Worthington D. G., Fairweather P. G., 1989 Shelter and food: interactions between *Turbo undulatum* (Archaeogastropoda: Turbinidae) and coralline algae on rocky seashores in New South Wales. Journal of Experimental Marine Biology and Ecology 129(1):61-79.
Wright J. M., Parker L. M., O'Connor W. A., Scanes E., Ross P. M., 2018 Ocean acidification affects both the predator and prey to alter interactions between the oyster *Crassostrea gigas* (Thunberg, 1793) and the whelk *Tenguella marginalba* (Blainville, 1832). Marine Biology 165:1-12.
Yamamoto T., 1997 Mode of reproduction and larval development of the tide pool dwelling whelk *Muricodrupa fusca*. Venus (Japanese Journal of Malacology) 56:131-143.
Yokochi H., 2004 Predation damage to corals. Coral Reefs of Japan, pp. 49-55.
Zhang H., Shin P. K., Cheung S. G., 2016 Physiological responses and scope for growth in a marine scavenging gastropod, *Nassarius festivus* (Powys, 1835), are affected by salinity and temperature but not by ocean acidification. ICES Journal of Marine Science 73(3):814-824.
Zuki Z. M., Lupo A. R., 2008 Interannual variability of tropical cyclone activity in the southern South China Sea. Journal of Geophysical Research: Atmospheres 113(6):1-14.
*** Hardy's Internet Guide to Marine Gastropods, 2021, https://www.gastropods.com
*** MolluscaBase, 2021, https://www.molluscabase.org
*** World Register of Marine Species, 2021, https://www.marinespecies.org

Received: 01 February 2024. Accepted: 30 May 2024. Published online: 16 June 2024.
Authors:
Siti Nur Hakimah Zainuddin, Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia, e-mail: p4448@pps.umt.edu.my
Lee Jen Nie, Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia, e-mail: jennie@umt.edu.my
Afiq Durrani Mohd Fahmi, Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia, e-mail: afiq.mohd@umt.edu.my
Izwandy Idris, South China Sea Repository & Reference Centre, Institute of Oceanography & Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia, e-mail: izwandy.idris@umt.edu.my
Nursalwa Baharuddin, Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia, e-mail: nursalwa@umt.edu.my

How to cite this article:
Zainuddin S. N. H., Nie L. J., Fahmi A. D. M., Idris I., Baharuddin N., 2024 Coral-grazing gastropods diversity in shallow reefs, Pulau Redang Marine Park, Terengganu, Malaysia. AACL Bioflux 17(3):1026-1038.