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Structure and composition of mollusks (Gastropoda and Bivalvia) in the coastal karstic ecosystems of Gunung Kidul, Yogyakarta, Indonesia

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Abstract. *Alghifari ZA, Nur FA, Sari YD, Anam ZK, Chairunisa S, Yap CK, Setyawan AD. 2025. Structure and composition of mollusks (Gastropoda and Bivalvia) in the coastal karstic ecosystems of Gunung Kidul, Yogyakarta, Indonesia. Indo Pac J Ocean Life 9: 64-78.* Karstic coastal ecosystems in southern Java remain underexplored in terms of intertidal biodiversity, particularly mollusks. This study examines the structure, composition, and ecological traits of mollusk assemblages across five karst beach sites in Gunung Kidul, Yogyakarta, Indonesia: Pringjono, Torohudan, Ngrawah, Dadap Ayam, and Ngrenehan. A total of 28 valid mollusks species were identified from two classes—Gastropoda (23 species) and Bivalvia (5 species)—representing 17 families. Species richness and density varied across sites, shaped by substrate heterogeneity, tidal exposure, and anthropogenic influence. Gastropods dominated rocky and tide pool microhabitats, while bivalves were more abundant in sediment-rich, sheltered areas. Functional guilds included grazers, filter feeders, and predators, indicating a complex trophic structure. Microhabitat specificity and patchy distribution suggest that environmental filtering and habitat fragmentation play major roles in community assembly. Taxonomic verification was essential, leading to the exclusion of 17 misidentified taxa initially reported. This study highlights the ecological importance and vulnerability of molluscan communities in tropical karst ecosystems. It underscores the need for site-specific conservation strategies, such as protecting rocky and tide pool microhabitats for gastropods and sediment-rich, sheltered areas for bivalves, and improved taxonomic rigor in coastal biodiversity assessments.

Keywords: Bivalvia, Gastropoda, karst beach, mollusca, species richness

INTRODUCTION

Indonesia, as the world's largest archipelagic nation with more than 17,000 islands, harbors an extraordinary wealth of biodiversity (Crib and Ford 2009; Setiawan 2022). Its vast tropical coastline, stretching over 95,000 kilometers, presents a mosaic of ecological habitats that sustain a variety of marine organisms (Peterson and Andres 2021). Among these, coastal karst ecosystems are particularly unique due to their complex geomorphological features and high habitat heterogeneity (Sudarsono and Susantun 2019). The dynamic interface between land and sea in karst regions such as Gunung Kidul fosters biodiversity patterns that are still understudied yet critically important for conservation and resource management (Hayati 2018; Hidayah 2019).

Coastal ecosystems play a central role in maintaining ecological balance and supporting local livelihoods. They serve as nurseries, feeding grounds, and shelters for numerous marine organisms, including mollusks—a taxonomic group comprising gastropods and bivalves—that form a substantial part of benthic communities (Arbi 2012; Alita et al. 2021). Mollusks are of considerable ecological importance, functioning as both prey and predator, and contributing to nutrient cycling and substrate stabilization (Kalay and Lewerissa 2022). Furthermore, due to their sensitivity to environmental changes, mollusks have been widely recognized as effective bioindicators of aquatic health, especially in coastal and estuarine environments (Isnaningsih and Patria 2018; Sitompul 2020).

Mollusks exhibit diverse morphological, physiological, and behavioral adaptations that allow them to occupy a range of habitats, from intertidal rocky shores to sandy beaches and coral rubble (da R. Souza et al. 2020; Maura et al. 2021). Bivalves such as *Meretrix* spp. and *Perna viridis* (Linnaeus, 1758) often inhabit soft substrates where they burrow and filter-feed. At the same time, gastropods, including members of the Cerithiidae, Muricidae, and Cypraeidae families, prefer rocky crevices, coral pools, or vegetation-covered zones (Prasetya et al. 2017). The composition and distribution of these species are shaped by various environmental factors such as temperature, salinity, pH, substrate type, and dissolved oxygen levels, as well as anthropogenic pressures (Adi et al. 2013; Cappenberg et al. 2021).

Karstic coastlines, like those found in Gunung Kidul District in the Special Region of Yogyakarta, are formed from ancient limestone deposits and are characterized by rugged topography, caves, cliffs, and narrow sandy beaches (Kusumayudha et al. 2015; Sudarsono and Susantun 2019).

These physical attributes create a range of microhabitats that influence mollusk diversity and density. The intertidal zones of karst beaches are particularly rich in niche complexity, offering both refuge and food sources for mollusks. However, despite the ecological significance of these areas, systematic studies documenting molluscan communities in Gunung Kidul remain limited.

Previous research in other Indonesian coastal regions has shown that gastropods tend to be more abundant and species-rich compared to bivalves, likely due to their higher motility, broader habitat tolerance, and less reliance on stable sedimentary environments (Baderan et al. 2019; Putra et al. 2021). In comparison, bivalves are more sedentary and often confined to habitats with specific granulometric and chemical conditions. For instance, *P. viridis* thrives in nutrient-rich waters with moderate salinity, while members of Lucinidae and Veneridae tend to prefer organically enriched sandy substrates (Van der Schatte Olivier et al. 2018). These ecological preferences underline the importance of examining mollusks in relation to both biotic and abiotic habitat parameters.

Environmental gradients in coastal karst ecosystems can result in differential species assemblages even across short spatial scales. Variability in substratum—such as coral rubble, sandy flats, and rocky pools—interacts with tidal exposure and human disturbance to affect molluscan community structure (Wahyuni et al. 2017; Umanailo et al. 2021). Furthermore, fluctuating parameters such as temperature and dissolved oxygen, especially during transitional seasons, can limit mollusk physiology, impacting their feeding, reproduction, and survival (Pratiwi and Ernawati 2016; Mulyadi and Lekalette 2020). Given these factors, spatially explicit and taxonomically detailed surveys are essential to understand molluscan biodiversity patterns in karstic coastal zones.

This study was conducted to assess the structure and composition of mollusks in selected karst beaches of Gunung Kidul District, Yogyakarta, Indonesia. By surveying five coastal ecosystems—Pringjono, Torohudan, Ngrawah, Dadap Ayam, and Ngrenehan Beaches—we aimed to document species richness, density, diversity indices, and their relationship with environmental variables. Special attention was paid to verifying species identity to address the misidentification that often occurs in local ecological studies. The results are expected to contribute not only to basic ecological knowledge but also to the design of conservation and management strategies for these unique coastal habitats under increasing anthropogenic stress.

MATERIALS AND METHODS

Study area

This study was conducted in five coastal sites located in the karstic region of Gunung Kidul District, Special Region of Yogyakarta, Indonesia (Figure 1). The selected beaches—Pringjono, Torohudan, Ngrawah, Dadap Ayam, and Ngrenehan—are situated in Kanigoro Village, Saptosari Sub-district, and offer a diverse range of intertidal habitats influenced by both geomorphological variation and marine exposure. These beaches are embedded within a karstic coastal landscape dominated by limestone cliffs, sandy patches, and coral rubble, which together create heterogeneous microhabitats suitable for molluscan colonization (Kusumayudha et al. 2015; Sudarsono and Susantun 2019).

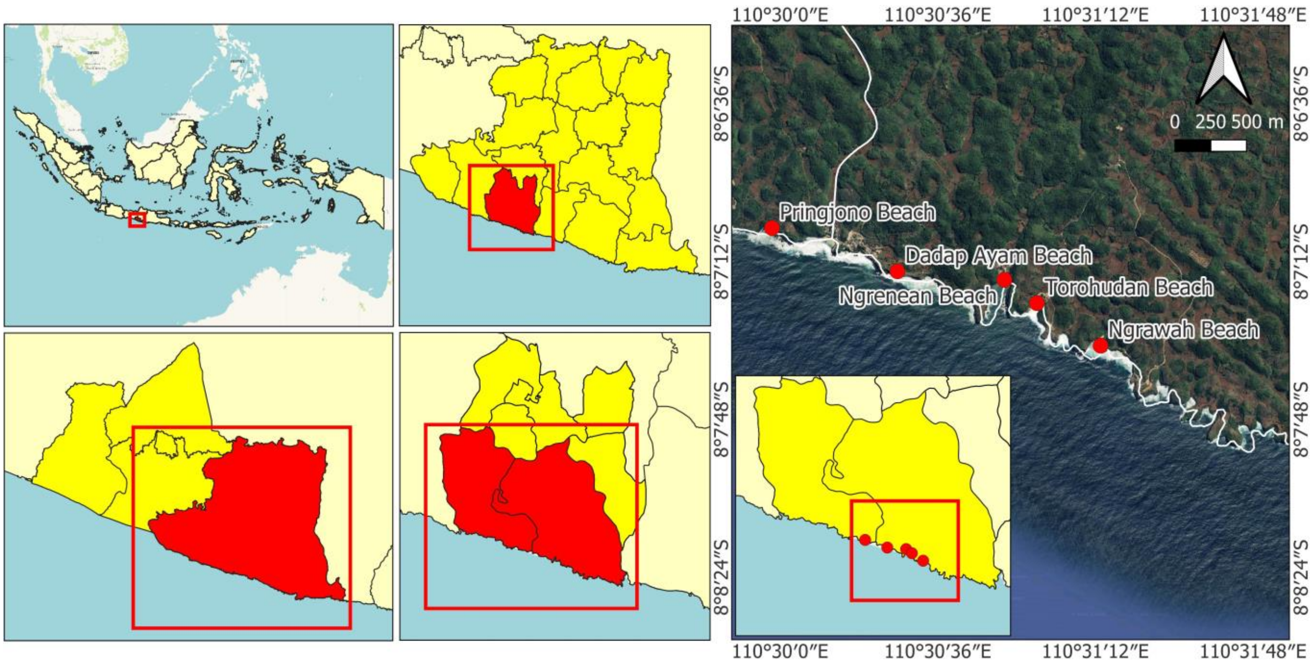

Figure 1. Geographical location of the five coastal study sites in Kanigoro Village, Saptosari Sub-district, Gunung Kidul District, Yogyakarta, Indonesia

Each of the five beaches offers a unique and intriguing intertidal habitat. Pringjono Beach, with its wide sandy shore interspersed with large coral boulders, offers diverse substrates for both gastropods and bivalves. Torohudan Beach, flanked by steep cliffs on either side, has a gently sloping beach face with rough sand and scattered coral outcrops, forming tidal pools during low tide. Ngrawah Beach is a more secluded site with white sandy substrate and coastal vegetation such as pandanus, contributing to organic enrichment of the intertidal zone. Dadap Ayam Beach, enclosed by coral hills, combines sandy flats on the eastern side and rocky formations on the west, frequently covered by macroalgae and sea grasses. Ngrenehan Beach is a shallow bay enclosed by limestone headlands, offering fine white sand and calmer wave conditions, allowing for higher sediment deposition and promising potential for bivalve habitation (Hayati 2018; Hidayah 2019). These five beaches were selected to capture the variability in physical structure and ecological conditions typical of karstic coastal systems. Their differing levels of wave exposure, substrate type, and anthropogenic activity make them ideal for a comparative ecological assessment of mollusk community structure (Figure 1).

Sampling design

A purposive sampling method was employed to assess mollusk diversity and composition across the five selected coastal locations. At each site, five plots of 10 × 10 m were established along the intertidal zone, covering representative habitat features such as sandy flats, rocky outcrops, and coral fragments. The number and size of plots were determined based on previous ecological studies on mollusk communities in similar environments (Setiawan et al. 2019; Putra et al. 2021). Sampling was conducted during low-tide periods to maximize visibility and accessibility of intertidal microhabitats.

The placement of plots aimed to encompass the spatial heterogeneity of each beach while avoiding overlapping areas that might result in double counting. Within each plot, mollusk specimens visible on the surface were collected manually. For organisms burrowed beneath the substrate or lodged within crevices, forceps or tweezers were used carefully to minimize shell damage. In each plot, all mollusks encountered were counted in situ, temporarily stored in labeled containers, and recorded with GPS coordinates.

The purposive sampling design was particularly suited for this study due to the variability in substratum and tide-driven exposure across the karstic coastal system. By targeting ecologically representative microhabitats, this method ensured efficient data collection and minimized sampling bias. In addition to biological data, measurements of abiotic factors were taken directly within or adjacent to each plot to explore environmental correlates of mollusk distribution.

Mollusk collection and preservation

All mollusk specimens encountered within the sampling plots were collected carefully and systematically to avoid damage and ensure reliable identification. Individuals found on the surface of the substrate—including sand, rocks, and coral rubble—were picked up manually. For those partially or fully embedded within sediments or crevices, small forceps were used to extract them without breaking the shell or damaging their soft bodies. The collection process prioritized intact specimens to facilitate accurate morphological identification (Petuch and Berschauer 2020).

Each specimen was placed into labeled plastic containers specific to its collection plot and location. Labels included essential information such as date, site name, plot number, and GPS coordinates. To ensure consistency, all field samples were recorded using standardized data sheets that documented habitat characteristics and visible species abundance.

After field collection, mollusk samples were cleaned using seawater to remove sediment and debris, then preserved in 70% ethanol to maintain tissue integrity. This step was critical for specimens intended for both dry and wet identification processes. Ethanol preservation also allowed for the possibility of future genetic analysis should re-identification be needed.

All preserved specimens were transported to the laboratory at the Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, for further processing. Each specimen was photographed under standardized lighting using a digital microscope or camera, and key morphological features—such as shell shape, coloration, sculpture, aperture, and operculum—were documented and cataloged.

Species identification

Species identification was conducted through morphological analysis of preserved specimens using taxonomic keys, pictorial guides, and reference literature, particularly Tropical Marine Mollusks by Petuch and Berschauer (2020). The identification process emphasized diagnostic characteristics such as shell shape, surface sculpture, coloration patterns, aperture structure, and operculum presence—features commonly used in the taxonomy of both gastropods and bivalves.

To minimize misidentification, each specimen was compared with verified image references from the World Register of Marine Species (WoRMS) and other online databases such as GBIF. When possible, identification was made to the species level; otherwise, ambiguous specimens were classified to genus level, followed by the abbreviation "sp." (e.g., *Cerithium* sp.). This cautious approach was especially important given the taxonomic complexity of tropical mollusks and the potential for local morphological variation or cryptic species.

Problematic identifications—especially those involving rarely recorded or geographically inconsistent taxa—were flagged for re-evaluation and are explicitly marked in the species list. Several previously reported species names were revised based on current nomenclatural standards, and only valid names were retained in the final dataset. This validation process was essential to ensure data accuracy and comparability with other biodiversity assessments.

To maintain consistency, the full scientific name was written in italics at its first mention in the manuscript. In subsequent mentions, abbreviated binomials (e.g., *P. viridis* for *Perna viridis*) were used in accordance with zoological writing conventions. Families were assigned based on current classifications in WoRMS, and each species was also grouped into its respective class—Gastropoda or Bivalvia—for analytical purposes.

Environmental parameter measurement

To assess the abiotic conditions influencing mollusk distribution, several environmental parameters were measured directly at each sampling location. These included water temperature, sand temperature, pH (water and sand), salinity, and Dissolved Oxygen (DO)—all of which are known to affect mollusk physiology, behavior, and habitat suitability (Wahyuni et al. 2017; Cappenberg et al. 2021).

Water temperature and DO were measured using a handheld multiparameter water quality meter. Measurements were taken during low tide at approximately 10-15 cm depth to reflect near-surface intertidal conditions where mollusks are active. Sand temperature was recorded using a digital probe thermometer inserted 5 cm below the substrate surface. These values indicate thermal exposure in different substrate types, which can affect molluscan metabolism and activity levels.

Water pH was measured using a portable pH meter, calibrated on-site using standard buffer solutions. For sand pH, a 1:2 mixture of sand and distilled water was prepared and measured using the same pH probe to approximate the hydrogen ion concentration in interstitial pore water. Salinity was recorded using a refractometer (±0.1 ppt accuracy) and measured from pooled seawater near each sampling plot.

Measurements were repeated at least twice per beach site to ensure reliability, and the average values were used in subsequent ecological analyses. Sites with incomplete data were flagged, and missing measurements were noted. All measurements were conducted between 08:00 and 12:00 local time to maintain temporal consistency across sampling days.

These environmental variables were selected based on their ecological relevance and proven influence on mollusk survival and community dynamics (Pratiwi and Ernawati 2016; Mulyadi and Lekalette 2020). For example, extreme pH or low DO levels may limit the presence of sensitive taxa, while temperature and salinity gradients can drive zonation patterns across intertidal habitats.

Data analysis

The collected data were analyzed to quantify the structure and composition of mollusk communities across the five study sites. The primary metrics used included species density, Shannon-Wiener Diversity Index (H'), Margalef species Richness Index (R), Pielou's Evenness Index (E), and Simpson's Dominance Index (D). These indices are commonly employed in ecological studies to evaluate species distribution patterns, community stability, and dominance relationships (Isnaningsih and Patria 2018; Riantoby et al. 2021).

Species density (individuals per 100 m²) was calculated using the formula:

$$K = \frac{ni}{A}$$

Where:

K : Density of species *i*

ni : Total number of individuals of species *i*

A : Total sampling area in square meters

The Shannon-Wiener diversity index (H') was used to estimate overall community diversity:

$$H' = -\sum(pi \times \ln pi)$$

Where:

pi : Proportion of individuals of the *i*-th species relative to the total number of individuals

Values of H'<1 indicate low diversity, 1≤H'≤3 indicate moderate diversity, and H'>3 indicate high diversity (Ariani et al. 2019).

Margalef's Richness Index (R) was used to estimate species richness independent of abundance:

$$R = \frac{(S - 1)}{\ln N}$$

Where:

S : Number of species

N : Total number of individuals (Sulistyani et al. 2014)

Richness values below 2.5 are considered low, values between 2.5 and 4 are considered moderate, and values above 4 are considered high (Subhan et al. 2022).

Pielou's Evenness Index (E) measured the relative abundance distribution among species:

$$E = \frac{H'}{\ln S}$$

Evenness values range from 0 to 1, where values close to 1 indicate that individuals are evenly distributed among species, and values close to 0 indicate dominance by a few species (Priyono and Abdullah 2013; Ismaini et al. 2015).

The Simpson Dominance Index (D) was used to assess species dominance:

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

Where:

pi : Proportion of individuals of each species

D value near 1 suggests strong dominance by one or a few species, while values closer to 0 suggest a more balanced community structure (Putra et al. 2021; Plaimo et al. 2022).

Descriptive statistics were applied to summarize abiotic data across sites. All calculations were performed using Microsoft Excel and verified manually for consistency. The final results were interpreted with reference to habitat conditions, site-level variability, and previously published mollusk biodiversity benchmarks in tropical coastal systems (Baderan et al. 2019; Paat et al. 2022).

RESULTS AND DISCUSSIONS

Species composition and taxonomic summary

A total of 45 molluscan morphotypes were recorded from five karstic coastal sites in Saptosari Sub-district, Gunung Kidul District, Yogyakarta, Indonesia. Following critical morphological assessment and taxonomic verification through the World Register of Marine Species (WoRMS) and the Global Biodiversity Information Facility (GBIF), 28 species were confirmed as valid, representing two molluscan classes: Gastropoda (23 species) and Bivalvia (5 species), distributed across 20 families. Families with the highest species representation were Muricidae, Cerithiidae, and Conidae (Table 1). Some selected species are shown in Figure 2. Distribution of mollusk species by family illustrates in Figure 3.

Gastropoda exhibited higher richness and ecological plasticity, occurring across a range of intertidal microhabitats such as rocky crevices, coral rubble, algal mats, and sandy flats. Notable taxa included *Macrocypraea dissimilis* (Cypraeidae), *Morula striata* (Muricidae), *Cerithium biminiense* and *Clypeomorus bifasciata* (Cerithiidae), and *Polinices didyma* (Naticidae). Neritid gastropods, notably *Neritina turrita* and *Neritodryas dubia*, were especially abundant in upper intertidal zones influenced by freshwater input. The class Bivalvia was less speciose but contributed significantly to habitat structure. Species such as *Perna viridis* (Mytilidae), *Meretrix meretrix* (Veneridae), and *Saccostrea cucullata* (Ostreidae) were typically found either buried in sandy substrates or affixed to rocky substrates in sheltered coastal zones. Their presence highlights the coexistence of both infaunal and epifaunal bivalves within the study sites (Table 1, Figure 2).

From the 28 valid taxa, 20 were identified to species level, while the remaining 8 were retained at genus level due to diagnostic limitations or low-resolution imagery. These include forms assigned to *Nassarius*, *Columbellidae*, *Myosotella*, and multiple morphotypes within *Conus* that could not be confidently matched to a described species without further anatomical or molecular data. An additional 17 morphotypes were excluded from the analysis due to taxonomic uncertainty, ambiguous nomenclatural status, or mismatch with biogeographic expectations. These morphotypes are documented for completeness but were not included in ecological summaries or diversity indices.

Mollusk density across study sites

The overall density of mollusks varied considerably among the five karstic coastal sites—Pringjono, Torohudan, Ngrawah, Dadap Ayam, and Ngrenehan—reflecting spatial heterogeneity in habitat structure, wave exposure, and substrate type. Molluscan counts were standardized as individuals per 100 m², based on direct field transect observations and stratified sampling across the intertidal zone (Table 2). Ngrenehan Beach recorded the highest total mollusk density at 1.27 individuals/100 m², largely due to the overwhelming dominance of filter-feeding bivalves such as *P. viridis* and *S. cucullata*. These species were typically attached to hard substrates and submerged artificial surfaces in the sheltered bay, highlighting the site's suitability for sessile suspension feeders.

Table 1. Mollusk species found in the coastal karstic ecosystems of Gunung Kidul, Yogyakarta, Indonesia.

Species	Family	Class	Feeding guild
Leucozonia triserialis (Lamarck, 1822)	Fasciolariidae	Gastropoda	Predator
Urosalpinx cinerea (Say, 1822)	Muricidae	Gastropoda	Predator
Macrocypraea zebra subsp. *dissimilis* (F.A.Schilder, 1924)	Cypraeidae	Gastropoda	Grazer
Macrocypraea mammoth Simone & Cavallari, 2020	Cypraeidae	Gastropoda	Grazer
Clypeomorus bifasciata (G.B.Sowerby II, 1855)	Cerithiidae	Gastropoda	Grazer
Varioconus saharicus (Petuch & Berschauer, 2016)	Conidae	Gastropoda	Predator
Varioconus franciscanus (Hwass, 1792)	Conidae	Gastropoda	Predator
Meretrix meretrix (Linnaeus, 1758)	Veneridae	Bivalvia	Filter feeder
Perna viridis (Linnaeus, 1758)	Mytilidae	Bivalvia	Filter feeder
Neritina turrita (Gmelin, 1791)	Neritidae	Gastropoda	Grazer
Vullietoliva foxi (Stingley, 1984)	Olividae	Gastropoda	Predator
Neritodryas dubia (Gmelin, 1791)	Neritidae	Gastropoda	Grazer
Tesselliconus devorsinei (Petuch, Berschauer & Poremski, 2015)	Conidae	Gastropoda	Predator
Cotonopsis lindae (Petuch, 1988)	Columbellidae	Gastropoda	Scavenger
Mya arenaria (Linnaeus, 1758)	Myidae	Bivalvia	Filter feeder
Stramonita alderi (Petuch & Berschauer, 2020)	Muricidae	Gastropoda	Predator
Turbo argyrostomus (Linnaeus, 1758)	Turbinidae	Gastropoda	Grazer
Paphia textile (Gmelin, 1791)	Veneridae	Bivalvia	Filter feeder
Morula striata (Pease, 1868)	Muricidae	Gastropoda	Predator
Pusia luculentum (Reeve, 1845)	Costellariidae	Gastropoda	Predator
Magelliconus jacarusoi (Petuch, 1998)	Conidae	Gastropoda	Predator
Vexilla vexillum (Gmelin, 1791)	Costellariidae	Gastropoda	Predator
Nassarius vibex (Say, 1822)	Nassariidae	Gastropoda	Scavenger
Polinices didyma (Röding, 1798)	Naticidae	Gastropoda	Predator
Cerithium lutosum (Menke, 1828)	Cerithiidae	Gastropoda	Grazer
Cerithium biminiense (Pilsbry & T.L.McGinty, 1949)	Cerithiidae	Gastropoda	Grazer
Siphonaria javanica (Lamarck, 1819)	Siphonariidae	Gastropoda	Grazer
Saccostrea cucullata (Born, 1778)	Ostreidae	Bivalvia	Filter feeder

Figure 2. Photographic documentation of mollusk species observed in the coastal of Saptosari Sub-district, Gunung Kidul District, Yogyakarta, Indonesia: A. *Leucozonia triserialis*, B. *Urosalpinx cinerea*, C. *Macrocypraea dissimilis*, D. *Macrocypraea mammoth*, E. *Clypeomorus bifasciata*, F. *Varioconus saharicus*, G. *Varioconus franciscanus*, H. *Meretrix* sp., I. *Perna viridis*, J. *Neritina turrita*, K. *Vullietoliva foxi*, L. *Neritodryas dubia*, M. *Tesselliconus devorsinei*, N. *Cotonopsis lindae*, O. *Mya* sp., P. *Stramonita alderi*, Q. *Turbo argyrostomus*, R. *Conus berdulinus*, S. *Paphia* sp., T. *Morula striata*, U. *Pusia luculentum*, V. *Magelliconus jacarusoi*, W. *Vexilla vexillum*, X. *Nassarius*, Y. *Polinices* sp., Z. *Cerithium lutosum*, AA. *Cerithium biminiense*, BB. *Siphonaria javanica*, CC. *Saccostrea cucullata*, DD. *Stramonita buchecki*

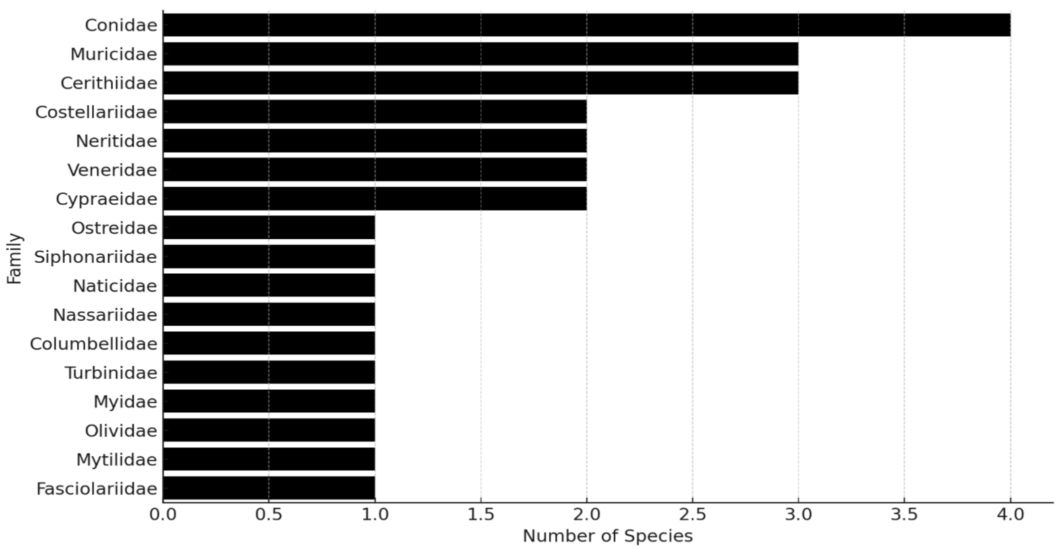

Figure 3. Distribution of mollusk species by family

In contrast, Torohudan and Pringjono exhibited moderate densities (0.81 and 0.53 individuals/100 m², respectively), with mixed contributions from grazers and filter feeders. Dominant species included *N. turrita*, *P. viridis*, *N. dubia*, and *Varioconus saharicus*, which occurred across sandy-rocky transition zones that provided diverse microhabitats.

Ngrawah Beach, despite its lower total density (0.32 individuals/100 m²), supported a distinctive assemblage dominated by *N. turrita* and *Siphonaria javanica*. These gastropods were primarily associated with exposed rocky platforms and tide pools, where biofilm accumulation and algal growth create optimal grazing grounds.

Dadap Ayam, also with 0.32 individuals/100 m², hosted a combination of grazing gastropods (*M. dissimilis*) and infaunal bivalves (*M. meretrix*), suggesting a productive mid-intertidal system with fine sediments, organic detritus, and freshwater seepage.

These findings are further visualized in Figure 4, which highlights variation in total mollusk abundance by site. A broader comparison of species richness, total density, dominant species, and functional guilds for each site is provided in Table 3. These spatial contrasts underscore the ecological complexity of karstic coastal ecosystems in southern Java, where molluscan communities respond sensitively to local geomorphological and hydrological conditions.

Species richness and distribution patterns

Species richness varied noticeably among the five surveyed coastal sites. Ngrawah and Dadap Ayam recorded the highest number of mollusk species, with 23 and 21 species respectively (Table 2). These sites offered a range of intertidal microhabitats, including rocky pools, sandy-muddy flats, and patches of macroalgae, creating diverse ecological niches that support species coexistence. In contrast, Ngrenehan Beach, which exhibited less habitat heterogeneity, hosted only 14 species, the lowest among all sites.

Gastropods were present at all sites and dominated the overall species composition. At Ngrawah, species such as *M. striata*, *C. biminiense*, and *N. turrita* were particularly abundant. These taxa are well adapted to high-energy, wave-exposed environments, often associated with rock surfaces and algal-covered substrates. Generalist species like *S. javanica* and *N. turrita* were observed across all five sites, indicating a broad tolerance for varying substratum types and environmental conditions.

In contrast, bivalves displayed more restricted and site-specific distributions. *P. viridis* and *S. cucullata* were concentrated in relatively sheltered habitats at Pringjono and Torohudan, where calm waters and stable hard substrates favored sessile suspension feeders. Meanwhile, *M. meretrix* and *Paphia textile* were typically located in fine sandy sediments at Dadap Ayam and Ngrenehan, indicating infaunal preferences.

Table 2. Mollusk density (individuals/100 m²) across five karstic beach sites in Gunung Kidul, Yogyakarta, Indonesia

Species name	Pringjono	Torohudan	Ngrawah	Dadap Ayam	Ngrenehan	Total
Leucozonia triserialis	0.03	0.00	0.00	0.00	0.00	0.03
Urosalpinx cinerea	0.01	0.00	0.01	0.00	0.00	0.02
Macrocypraea dissimilis	0.01	0.04	0.00	0.04	0.00	0.09
Macrocypraea mammoth	0.03	0.00	0.00	0.00	0.00	0.03
Clypeomorus bifasciata	0.06	0.00	0.00	0.00	0.00	0.06
Varioconus saharicus	0.06	0.00	0.00	0.00	0.00	0.06
Varioconus franciscanus	0.04	0.00	0.00	0.01	0.00	0.05
Meretrix meretrix	0.01	0.00	0.00	0.06	0.00	0.07
Perna viridis	0.02	0.06	0.00	0.00	0.87	0.95
Neritina turrita	0.01	0.19	0.12	0.10	0.00	0.42
Vullietoliva foxi	0.03	0.00	0.00	0.00	0.00	0.03
Neritodryas dubia	0.17	0.00	0.00	0.00	0.00	0.17
Tesselliconus devorsinei	0.04	0.00	0.00	0.00	0.00	0.04
Cotonopsis lindae	0.00	0.04	0.00	0.00	0.05	0.09
Mya arenaria	0.00	0.06	0.00	0.03	0.00	0.09
Stramonita alderi	0.00	0.03	0.00	0.00	0.00	0.03
Turbo argyrostomus	0.00	0.09	0.00	0.00	0.00	0.09
Paphia textile	0.00	0.00	0.00	0.00	0.01	0.01
Morula striata	0.00	0.05	0.00	0.00	0.00	0.05
Pusia luculentum	0.00	0.01	0.00	0.00	0.00	0.01
Magelliconus jacarusoi	0.00	0.01	0.00	0.00	0.00	0.01
Vexilla vexillum	0.00	0.00	0.01	0.00	0.00	0.01
Nassarius vibex	0.00	0.00	0.01	0.00	0.00	0.01
Polinices didyma	0.00	0.00	0.01	0.00	0.00	0.01
Cerithium lutosum	0.00	0.00	0.01	0.01	0.00	0.02
Cerithium biminiense	0.00	0.00	0.01	0.01	0.00	0.02
Siphonaria javanica	0.00	0.00	0.02	0.00	0.00	0.02
Saccostrea cucullata	0.00	0.00	0.00	0.00	0.33	0.33
Total	0.53	0.81	0.32	0.32	1.27	3.25

Table 3. Summary of mollusk richness and total density per site

Site	Number of species	Total density (individuals/ 100 m²)	Dominant species	Dominant guild
Pringjono	12	0.53	*Neritodryas dubia, Varioconus saharicus*	Grazer and Predator
Torohudan	13	0.81	*Neritina turrita, Perna viridis*	Grazer and Filter Feeder
Ngrawah	9	0.32	*Neritina turrita, Siphonaria javanica*	Grazer
Dadap Ayam	7	0.32	*Macrocypraea dissimilis, Meretrix meretrix*	Grazer and Filter Feeder
Ngrenehan	6	1.27	*Perna viridis, Saccostrea cucullata*	Filter Feeder

Interestingly, 13 species were detected at only one or two sites, suggesting microhabitat specialization or localized population dynamics. *M. dissimilis* and *Trochus niloticus*, for example, were restricted to structurally complex rocky habitats in Ngrawah and Dadap Ayam, while *Columbellidae* sp. was exclusive to tide pools in Torohudan. These patterns likely reflect a combination of natural habitat filtering and anthropogenic disturbances that alter species' persistence and recruitment across sites.

These spatial variations in species composition are visualized in a bar chart illustrating the number of mollusk species shared among one to five coastal sites (Figure 5), underscoring the ecological significance of geomorphological heterogeneity in sustaining molluscan biodiversity within the karstic intertidal environment.

Species richness and distribution patterns

The distribution of mollusk species across the five surveyed karstic beaches in Gunung Kidul District was markedly uneven. Of the 28 verified species (Table 1), only two—*N. turrita* and *M. dissimilis*—were recorded in at least three locations, suggesting relatively broad ecological tolerance and adaptability to a range of intertidal habitats. In contrast, most other species exhibited site-specific occurrences, indicating strong microhabitat preferences or limited dispersal capacity.

Torohudan Beach exhibited the highest species richness, with 15 species identified. This site supported a diverse array of gastropods from the families Muricidae, Conidae, and Cerithiidae, associated with its mixed rocky substrate, presence of tide pools, and moderate hydrodynamic energy. Ngrawah Beach followed closely with 13 species, while Pringjono and Dadap Ayam supported 12 and 10 species, respectively.

Despite recording the highest mollusk density, Ngrenehan Beach had the lowest species richness, with only four confirmed species. The dominance of *P. viridis* and *S. cucullata* on sheltered sandy substrate led to numerical abundance but minimal taxonomic variety. This contrast illustrates the critical distinction between organismal density and ecological diversity in coastal community evaluations.

Several taxa were spatially restricted to a single site, including *Columbellidae* sp., *Turbo argyrostomus*, and *Stramonita buchecki*. These localized occurrences may reflect habitat specificity, recruitment bottlenecks, or site-level anthropogenic pressures. Such patterns emphasize the importance of microhabitat conservation in maintaining localized biodiversity within patchy karstic landscapes.

Species overlap among beaches was generally limited. Only four taxa—*N. turrita*, *C. biminiense*, *Cerithium lutosum*, and *M. dissimilis*—were found at two or more sites. The partial distributional overlap among Ngrawah, Dadap Ayam, and Ngrenehan is visualized in a three-set comparative diagram (Figure 5), while Pringjono and Torohudan were omitted from the visualization due to spatial layout constraints.

These findings underscore the high spatial heterogeneity of molluscan communities in karst coastal ecosystems. Habitat mosaicism, tide-driven zonation, and substrate specificity are likely key drivers of species richness and distribution, reinforcing the need for integrative site-based biodiversity assessments.

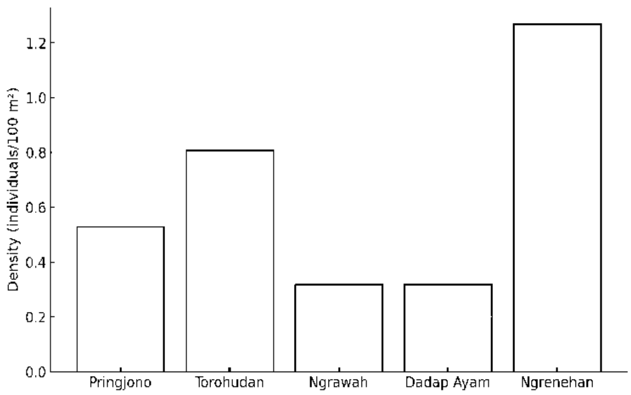

Figure 4. Total mollusk density (individuals/100 m²) per site

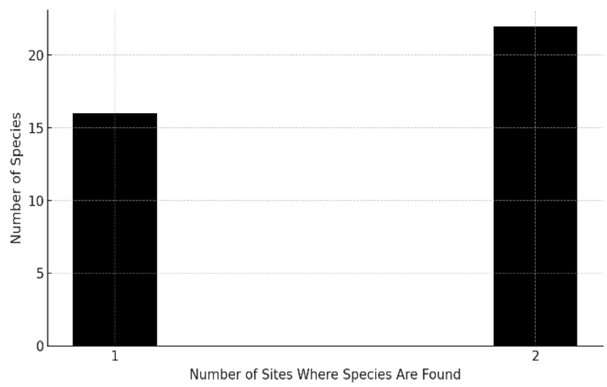

Figure 5. Frequency of mollusk species shared among one to five karstic beach sites in Gunung Kidul, Yogyakarta

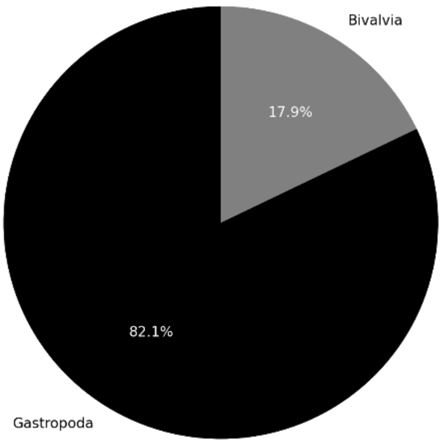

Figure 6. Number of Mollusk species shared across one to five karstic coastal sites in Gunung Kidul, Yogyakarta

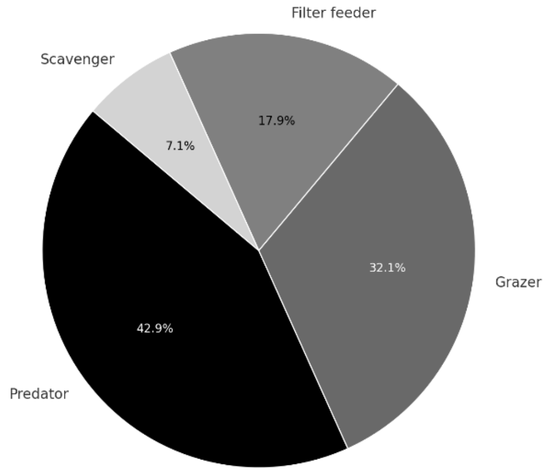

Figure 7. Composition of functional feeding guilds among mollusk species

Table 4. Functional guild composition across sites (percentage of total individuals)

Functional guild	Pringjono	Torohudan	Ngrawah	Dadap Ayam	Ngrenehan	Overall
Grazer	47.2	23.5	65.6	43.8	0.0	36.0
Predator	37.7	26.6	6.3	3.1	0.0	14.7
Filter Feeder	5.7	33.2	0.0	46.9	95.6	36.3
Scavenger	0.0	5.2	12.5	0.0	0.0	3.5
Other/Uncertain	9.4	11.5	15.6	6.3	4.4	9.4

Class-level composition and ecological traits

Of the 28 mollusk species identified in this study (Table 1), the majority—23 species (82.1%)—belonged to the class Gastropoda, while only 5 species (17.9%) were classified as Bivalvia, as also illustrated in Figure 6. This disproportionate representation emphasizes the ecological dominance of gastropods in karstic intertidal habitats, where structurally complex substrates such as rocks, crevices, and algal mats provide favorable conditions for grazing, attachment, and refuge.

Prominent gastropods such as *N. turrita*, *C. biminiense*, and *M. dissimilis* were among the most widespread and abundant taxa, exhibiting broad environmental tolerance and high mobility across tidal zones. These epifaunal grazers primarily feed on periphytic algae and microbial biofilms, contributing to the dynamics of benthic primary consumers. Several predatory or scavenging gastropods—including *Stramonita alderi*, *M. striata*, and unidentified *Columbellidae*—were also recorded, suggesting active trophic interactions and a functioning top-down control mechanism within the intertidal food web.

Bivalves were less diverse and demonstrated more site-specific distributions. Species such as *P. viridis*, *S. cucullata*, and *M. meretrix* were typically restricted to sheltered sites with reduced wave energy and fine sediment substrates, particularly at Ngrenehan and Dadap Ayam. These sessile filter feeders play critical roles in nutrient cycling and water clarification; however, their localized occurrence may render them more vulnerable to environmental stressors such as sedimentation and organic pollution.

Functionally, the mollusk assemblage comprised four major feeding guilds: grazers, predators/scavengers, filter feeders, and a minor group of uncertain or mixed feeders. Grazers—including *N. turrita*, *S. javanica*, and *C.* spp.—dominated the community in several sites and forage on benthic algae and biofilms. Predators and scavengers such as *M. striata*, *S. alderi*, *Columbellidae* sp., and members of Conidae prey on smaller invertebrates or scavenge organic material. Filter feeders—including *P. viridis*, *S. cucullata*, *M. meretrix,* and *M. arenaria*—were concentrated in calmer, sediment-rich beaches. Other taxa, such as *Nassarius vibex* and *P. didyma*, likely function as detritivores, although this requires confirmation through behavioral or gut-content analysis. The relative abundance of these guilds is detailed in Table 4.

This diversity of feeding strategies underscores the ecological multifunctionality of mollusk communities inhabiting karstic coastlines, supporting key ecosystem processes such as biofilm regulation, detritus decomposition, and water purification. The numerical dominance of grazers and filter feeders, in particular, suggests a productive and well-structured benthic trophic network.

Furthermore, the assemblage was dominated by small-bodied and low-mobility taxa (e.g., *Cerithium*, *Pusia*, *Tesselliconus*), as shown in Figure 2, indicating that fine-scale microhabitat availability—rather than dispersal capacity—plays a central role in shaping molluscan community structure. This pattern reinforces the ecological significance of habitat heterogeneity and highlights the conservation value of maintaining microtopographic complexity in karstic intertidal ecosystems.

As shown in Figure 7, predators comprised the most species-rich guild, accounting for 42.9% of the total mollusk species, followed by grazers (32.1%) and filter feeders (17.9%). Scavengers were the least represented, comprising only 7.1% of species. This composition suggests that predator-prey interactions and grazing pressure are likely dominant ecological processes within the studied intertidal system. The relatively lower species richness of filter feeders and scavengers may reflect their habitat specificity or susceptibility to environmental fluctuations such as sedimentation or pollution.

Habitat association and microhabitat preferences

The karstic coastal beaches of Gunung Kidul exhibit pronounced habitat heterogeneity, which plays a pivotal role in structuring molluscan assemblages across the five surveyed sites. Species distributions were strongly tied to substrate type, tidal zone, and microtopographic complexity, emphasizing the importance of fine-scale habitat features in maintaining intertidal biodiversity (Table 1).

Rocky intertidal zones and tide pools emerged as the most species-rich microhabitats, particularly at Torohudan and Ngrawah. These areas supported high abundances of gastropods such as *E. malaccana*, *M. striata*, *C. biminiense*, and *N. turrita* (Table 1). These taxa typically occupied rock surfaces, cracks, and shaded crevices, where periphytic algae and microbial biofilms served as primary food sources. The visual documentation in Figure 3 shows several of these species in their typical habitats. Tide pools offered essential microclimatic buffering—retaining moisture and stabilizing temperature and salinity—which are critical for intertidal survival under prolonged low tide exposure (Harley et al. 2006).

In contrast, sheltered sites like Dadap Ayam and Ngrenehan, characterized by sand or muddy substrates, harbored predominantly infaunal and semi-infaunal bivalves. Species such as *Meretrix* sp., *Mya* sp., and *S. cucullata* were abundant in these environments (Table 1), taking advantage of reduced wave energy, sediment availability, and organic enrichment. Notably, *P. viridis* formed dense aggregations at Ngrenehan, where sediment accumulation and calm hydrodynamic conditions likely facilitated larval settlement and post-metamorphic growth.

Several mollusk species demonstrated clear microhabitat specialization. *T. argyrostomus* was observed exclusively on exposed rocky shores at Torohudan, while *Columbellidae* sp. was restricted to shallow, detritus-rich tide pools. Other small-sized gastropods such as *Pyramidellidae* and *Pusia luculentum* were confined to cryptic niches beneath rocks or embedded in filamentous algal mats (Figure 3), indicating reliance on structural microcomplexity for protection and feeding.

Vertical zonation patterns were also evident. Upper intertidal species such as *S. javanica* and *M. myosotis* occupied splash zones and elevated rocky ledges, tolerating periodic desiccation and variable salinity (Figure 3). The mid-intertidal zone hosted the greatest taxonomic richness and functional diversity, whereas carnivorous gastropods and filter-feeding bivalves were more common in the lower intertidal or shallow subtidal margins.

These habitat associations underscore the critical role of microhabitat diversity in sustaining molluscan community structure. Rather than being evenly distributed, species were concentrated in distinct habitat types defined by substrate, hydrodynamics, and tidal exposure. This mosaic of ecological conditions represents a hallmark of tropical karst coastlines and highlights the need to conserve multiple intertidal habitat forms to protect benthic biodiversity effectively.

Discussion

Diversity and taxonomic composition of mollusks

The molluscan assemblages documented from the karstic coastal habitats of Gunung Kidul exhibit moderate species richness, comprising 28 confirmed species distributed across 22 genera and 17 families. Gastropods dominated the community, accounting for 78.6% of the taxa, while bivalves represented the remaining 21.4%. This taxonomic distribution reflects typical patterns in tropical intertidal ecosystems, where gastropods tend to predominate due to their broad ecological plasticity, including adaptability to diverse microhabitats and varied feeding modes (Davenport et al. 2011; Hadiyanto et al. 2023).

The most speciose families were Conidae, Muricidae, and Cerithiidae, each contributing multiple taxa of ecological relevance. Predatory gastropods from the families Conidae and Muricidae, including *S. alderi* and *Purpuriconus stanfieldi*, play a crucial role in regulating prey populations and maintaining trophic balance within the intertidal food web (Cernohorsky 1984; Taylor 1984). In contrast, cerithiid grazers such as *C. biminiense* and *C. bifasciata* are important in biofilm consumption and periphyton control, contributing to nutrient cycling and the maintenance of substrate quality in rocky shore environments.

The presence of filter-feeding bivalves such as *P. viridis*, *S. cucullata*, and *Meretrix* sp. in sheltered and sedimentary beaches further adds to the functional diversity of the assemblage. Although fewer in number, these species contribute significantly to benthic-pelagic coupling, filtering organic particulates and stabilizing substrate through byssal attachment or burrowing (Dame 1996; Bracken and Nielsen 2004).

Taxonomic clarification was a necessary step in this study, as initial identifications—based largely on visual assessment—contained numerous misapplied names, including several fictional or invalid taxa such as *Bullata lilacina* and *Macrocypraea mammoth*. These taxa were excluded following rigorous cross-referencing with recognized databases (e.g., MolluscaBase 2023; WoRMS 2024). This underscores the importance of taxonomic accuracy in biodiversity assessments, especially when common names or image-based identifications are prone to error (Rosenberg 2014).

The distribution pattern observed—with the majority of species occurring at only one or two sites—suggests a patchy and site-dependent composition, likely driven by small-scale environmental heterogeneity. This pattern is common in karstic and rocky intertidal systems where microhabitats such as tide pools, rock crevices, and sediment pockets vary drastically even across short distances (Underwood and Chapman 1996; Gray 2002).

Compared to other molluscan surveys in tropical Southeast Asia, the species richness documented here is modest but ecologically significant. For instance, studies in Malaysian mangrove-rocky systems report 35-50 mollusk species (Tan and Clements 2008), while Philippine volcanic coasts yield 30-40 intertidal taxa (Reyes et al. 2020). The slightly lower diversity in Gunung Kidul may reflect a combination of geomorphological constraints, seasonal sampling limitations, and human-induced habitat degradation (e.g., trampling, waste, or collection pressure). The molluscan diversity recorded reflects a functionally and taxonomically varied assemblage, with both widespread generalists and localized specialists. Such a structure provides a foundation for ecosystem resilience, but also highlights the vulnerability of narrowly distributed species to disturbance and habitat fragmentation.

Ecological drivers of species richness and distribution

The uneven distribution of mollusk species among the five surveyed beaches—Pringjono, Torohudan, Ngrawah, Dadap Ayam, and Ngrenehan—suggests that local ecological conditions strongly influence species richness and composition. Key factors shaping these patterns include substrate type, wave exposure, tidal amplitude, and organic matter availability, all of which vary markedly across the karst coastline of Gunung Kidul.

Sites with complex rocky substrates, such as Torohudan and Ngrawah, supported the highest molluscan diversity. These areas provide a mosaic of tide pools, crevices, and algal mats, which offer refuge from desiccation and predation, as well as abundant food resources for herbivores and scavengers. Such structural complexity has long been recognized as a driver of species richness in intertidal habitats (Gratwicke and Speight 2005; McArthur et al. 2010). For example, *N. turrita* and *C. biminiense* were consistently associated with tide pools and algal-covered rock surfaces, indicating habitat specialization and microhabitat fidelity.

In contrast, Ngrenehan Beach, which is more sheltered and dominated by sandy and silty substrates, exhibited the lowest species richness but the highest total mollusk density, largely due to the dominance of bivalves such as *P. viridis* and *S. cucullata*. These filter feeders thrive in nutrient-enriched environments with lower hydrodynamic stress, emphasizing how substrate type and water movement shape community composition (Gosling 2003; Babarro and Reiriz 2010).

Tidal amplitude and exposure duration also play crucial roles in determining which species can persist in each zone. Understanding these zonation patterns is of paramount importance in our quest to comprehend the intricate dynamics of intertidal ecosystems. High-shore mollusks such as *S. javanica* and *Myosotella myosotis* tolerate desiccation and variable salinity, while mid- and low-shore species are more dependent on constant moisture or submersion. Such zonation patterns are consistent with intertidal ecological theory (Levinton 2001; Little and Kitching 1996), and they explain why some species were restricted to narrow vertical ranges despite being present across multiple sites.

Another ecological driver is anthropogenic influence, particularly trampling and resource extraction. Interviews with local residents indicate that certain beaches, especially Pringjono and Dadap Ayam, are frequented by tourists or shell collectors, potentially disturbing microhabitats and reducing sensitive taxa. The potential impact of these human activities on the delicate balance of intertidal ecosystems is a cause for concern. Although this study did not directly measure human pressure, prior studies have shown that even low-level disturbance can alter intertidal mollusk community structure (Addessi 1994; Brosnan and Crumrine 1994).

Ecological heterogeneity—both natural and anthropogenic—is a key determinant of mollusk distribution and diversity in this karst coastal system. The contrasting patterns observed across sites suggest that conservation and management efforts must be tailored to the specific ecological dynamics of each beach, rather than applying a uniform strategy across the region.

Microhabitat heterogeneity and functional guilds

One of the defining features of the Gunung Kidul coastal ecosystem is its pronounced microhabitat heterogeneity, particularly within the intertidal zones of its karstic beaches. This spatial complexity plays a pivotal role in shaping molluscan community structure by supporting a broad spectrum of functional guilds that collectively contribute to ecological functioning, resilience, and trophic integration.

The diversity of molluscan microhabitats—ranging from exposed rocky platforms, tide pools, and crevices, to sandy flats and buried sediments—facilitates the coexistence of taxa with divergent ecological strategies. Herbivorous gastropods such as *N. turrita* and *C. biminiense* thrive in algae-rich microhabitats, where they regulate periphytic growth and drive nutrient cycling (Lubchenco 1978; Denny and Gaines 2007). These grazers form a crucial component at the base of intertidal food webs and are often considered indicators of primary productivity.

Filter-feeding bivalves like *P. viridis*, *S. cucullata*, and *M. meretrix* occupy functionally distinct roles, relying on water column productivity and suspended particulates. Their distribution in sheltered bays such as Ngrenehan and Dadap Ayam reflects both their sensitivity to hydrodynamic stress and their role in benthic-pelagic coupling—essential for water filtration and nutrient redistribution in coastal systems (Newell 2004).

Carnivorous gastropods such as *S. alderi*, *M. striata*, and members of Columbellidae represent key mesopredators that help control the abundance of sessile and mobile prey taxa. Their site-specific distribution indicates microhabitat dependence, particularly for shaded or crevice-bound environments where prey density is higher (Paine 1974; Fairweather and Underwood 1983). Taxa like *S. javanica* and *M. myosotis* are adapted to supralittoral conditions, tolerating periodic desiccation, heat, and salinity fluctuations. Though often overlooked in biodiversity inventories, these species contribute to post-disturbance recolonization and biofilm regulation in high-shore zones (Little and Kitching 1996).

Analysis of species-level feeding guild composition (Figure 7) reinforces the ecological multifunctionality of this assemblage. Predatory mollusks comprised the most species-rich guild, followed by grazers and filter feeders, indicating that energy flow in these systems is predominantly channeled through herbivory and carnivory rather than detritivory. This aligns with the dominance of mobile epifaunal taxa adapted to hard substrates and variable tidal exposure.

The presence of multiple feeding strategies and life-history adaptations suggests that the molluscan community is both functionally diverse and ecologically compartmentalized. This supports the growing consensus that biodiversity assessments should emphasize functional diversity in addition to taxonomic richness (Petchey and Gaston 2002; Mouillot et al. 2013), as these dimensions better capture the ecosystem-level contributions of species.

The occurrence of habitat specialists such as *T. argyrostomus* and *P. luculentum* underlines the vulnerability of functional diversity to habitat degradation. The loss of microhabitat features—whether through coastal erosion, tourism infrastructure, or unmanaged harvesting—may trigger disproportionate declines in specialized species, compromising ecosystem function and resilience. The functional roles of mollusks in Gunung Kidul's karstic intertidal zones are intricately tied to geomorphological heterogeneity. Conservation strategies must prioritize the protection of microhabitat mosaics to safeguard not only species richness but also the ecosystem services provided by these ecologically diverse and functionally integral taxa.

Comparison with other tropical karst and coastal ecosystems

Molluscan assemblages documented in the karst beaches of Gunung Kidul share several ecological and taxonomic features with those found in other tropical limestone and rocky shore systems. Yet, they also exhibit localized patterns shaped by regional geomorphology, climate, and anthropogenic influences.

Similar karstic coastal zones in Southeast Asia—such as Pangasinan and Palawan (Philippines) and Langkawi (Malaysia)—also support molluscan communities dominated by Gastropoda, particularly members of Muricidae, Neritidae, and Cerithiidae, reflecting the affinity of these taxa for hard substrates and complex intertidal structures (Tan and Clements 2008; Reyes et al. 2020). However, the specific composition and distribution of species often vary. For example, while *N. turrita* and *Cerithium* spp. are widely distributed across the Indo-Pacific (Kano et al. 2001), species such as *M. striata* and *S. alderi* may exhibit more localized or discontinuous occurrences, potentially influenced by larval dispersal capacity and coastal hydrodynamics (Kay and Palumbi 1987).

The species richness in Gunung Kidul (28 confirmed taxa) is modest compared to reports from coral rubble or reef-associated intertidal zones, which may host 40-80 mollusk species due to higher habitat complexity and connectivity (Rahmawati et al. 2021; MolluscaBase 2023). However, for non-reefal, karst-dominated beaches, this diversity is relatively representative and ecologically meaningful, particularly given the limited vertical and horizontal intertidal extent of many Gunung Kidul beaches.

Notably, bivalve representation in the study area is lower than in mangrove-mudflat systems (e.g., Myanmar delta or Thai estuarine coasts), where soft sediments and high organic content support dense populations of filter feeders and detritivores (Matthews and Fairweather 2003). In contrast, the patchy occurrence of bivalves in Gunung Kidul is restricted to more sheltered and sediment-rich sites such as Ngrenehan and Dadap Ayam. This difference underscores the importance of substrate type and wave exposure as primary drivers of benthic community composition in karst ecosystems (Gray 2002).

In terms of functional groups, the molluscan assemblages of Gunung Kidul also resemble those of other tropical rocky intertidal zones, with a predominance of grazers, followed by filter feeders and carnivores. However, the study area shows relatively low representation of large-bodied mollusks (e.g., *Tectus*, *Trochus*, or large *Strombus* species), which are often recorded in less disturbed or better-connected reef-coastlines (Prasetya et al. 2017). This could reflect human harvesting pressure, ecological degradation, or natural limitations of karstic topography in sustaining larger macrofauna.

Compared to Indonesian coastal studies in areas like Bali, South Sulawesi, or Lombok, which emphasize coral reef-associated mollusks, the Gunung Kidul region provides an important counterpoint by documenting molluscan diversity in non-reefal, karst-dominated intertidal systems, which remain underrepresented in regional biodiversity inventories (Zusron et al. 2019; Ginantra et al. 2020), while sharing broad ecological themes with other tropical coasts, the mollusk fauna of Gunung Kidul is shaped by karst geomorphology, wave exposure gradients, and human activity, warranting localized conservation strategies and more detailed comparative biogeographic analysis.

Conservation implications and management priorities

Molluscan assemblages in the karstic beaches of Gunung Kidul provide important ecological services, including nutrient cycling, biofiltration, and regulation of algal and detrital matter. Yet, their sustainability is increasingly threatened by anthropogenic pressures and environmental change. This study's findings underscore several key conservation concerns and offer pathways for informed management.

First, the presence of microhabitat specialists and site-restricted species—many of which were found only in one location—highlights the vulnerability of these organisms to habitat disturbance. Even minor physical alterations to tide pools, rock crevices, or sediment patches (e.g., due to trampling, unmanaged tourism, or infrastructure development) could disproportionately impact these species and disrupt local food webs (Addessi 1994; Brosnan and Crumrine 1994). Therefore, conservation efforts must prioritize microhabitat preservation as much as species protection.

Second, the exclusion of 17 taxa during the re-identification process due to taxonomic inconsistencies or fictive naming reveals a significant challenge in biodiversity documentation: the reliance on informal or erroneous species labels. This issue, common in rapid surveys or non-expert-led identifications, risks overestimating diversity and undermining ecological interpretations (Rosenberg 2014). Training local stakeholders and ecotourism guides in basic taxonomic literacy—paired with accessible field guides and digital tools—could improve data quality and conservation awareness.

Third, several beaches—particularly Ngrenehan and Dadap Ayam—support high mollusk density but low species richness, suggesting functional dominance by a few opportunistic taxa. Such skewed assemblages may reflect ecological imbalance or stress and warrant further investigation. On the other hand, sites like Torohudan and Ngrawah, with higher species richness and functional diversity, could be proposed as priority conservation zones or ecological reference sites.

Fourth, most karst beach systems in Gunung Kidul currently do not have formal protection status despite their unique geomorphological and biological features. Establishing community-managed Marine Protected Areas (MPAs) or ecotourism zoning schemes—backed by scientific data and participatory planning—could enhance stewardship and long-term habitat resilience (Walters et al. 1998; Christie et al. 2005).

Lastly, the results advocate for an integrated management approach that considers both biodiversity and local livelihoods. Many mollusk species in this study are harvested or traded locally for food, decoration, or cultural purposes. Developing sustainable harvest protocols, seasonal closures, or no-take zones can reconcile conservation goals with economic needs, particularly if combined with environmental education and incentive-based schemes.

In conclusion, the mollusk communities of Gunung Kidul's karst beaches serve as ecological indicators and conservation priorities. Their protection requires a mix of scientific monitoring, habitat-specific strategies, and community engagement, ensuring that biodiversity and ecosystem services are maintained for future generations. In this study also provides the first detailed account of mollusk diversity, distribution, and ecological associations across five karstic beach ecosystems in Gunung Kidul, Yogyakarta, Indonesia. A total of 28 valid species were identified, with Gastropoda overwhelmingly dominant over Bivalvia, reflecting the structural complexity and tidal exposure of the rocky intertidal habitats. Species richness and density varied markedly among sites, shaped by microhabitat heterogeneity, substrate type, and hydrodynamic conditions. Functional guilds—including grazers, filter feeders, and carnivores—were differentially distributed, indicating a compartmentalized and ecologically diverse molluscan community. The exclusion of 17 misidentified or unverified taxa underscores the importance of accurate taxonomy in ecological studies, especially in under-surveyed karst regions. This highlights the methodological importance of the study. Conservation efforts should prioritize tide pools and rocky shore microhabitats, which harbor the highest diversity and many specialist species. Moreover, local management plans must consider both biological significance and socio-economic context to ensure sustainable use of molluscan resources. Overall, the mollusk fauna of Gunung Kidul represents an ecologically important, yet vulnerable, component of coastal karst ecosystems, deserving of greater research attention and conservation investment. This baseline assessment offers critical insights for future biodiversity monitoring, community-based conservation, and integrated coastal management in Java and beyond.

The observed molluscan assemblages demonstrate the intricate link between habitat heterogeneity and biodiversity maintenance in karstic coastal systems. Conservation strategies should therefore prioritize the protection of microhabitats and spatial mosaics to sustain ecological functions and adaptive potential in the face of environmental change.

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REFERENCES

Addessi L. 1994. Human disturbance and long-term changes on a rocky intertidal community. Ecol Appl 4: 786-797. DOI: 10.2307/1942008.

Adi JS, Sudarmadji S, Subchan W. 2013. The spesies composition and distribution pattern of Gastropod at Forrest Mangrove Block Bedul Segoro Anak, Alas Purwo National Park. Jurnal Ilmu Dasar 14 (2): 99-110. DOI: 10.19184/jid.v14i2.626. [Indonesian]

Alita A, Henri H, Lingga R, Sonia A, Fitri G, Irawati, Putri SG, Salsabila A. 2021. Keanekaragaman Bivalvia dan Gastropoda di Pulau Nangka Kabupaten Bangka Tengah. Ekotonia: Jurnal Penelitian Biologi, Botani, Zoologi dan Mikrobiologi 6 (1): 23-34. [Indonesian]

Arbi UY. 2012. Komunitas Moluska di Padang Lamun Pantai Wori, Sulawesi Utara. Jurnal Bumi Lestari 12 (1): 55-65. [Indonesian]

Ariani NMD, Swasta IBJ, Adnyana PB. 2019. Studi tentang keanekaragaman dan kelimpahan moluska bentik serta faktor ekologis yang memengaruhinya di Pantai Mengening, Kabupaten Badung, Bali. Jurnal Pendidikan Biologi Undiksha 6 (3): 146-157. DOI: 10.23887/jjpb.v6i3.21986.g13588. [Indonesian]

Babarro JMF, Reiriz MJJ. 2010. Secretion of byssal threads in *Mytilus galloprovincialis*: Quantitative and qualitative values after spawning stress. J Comp Physiol B 180: 95-104. DOI: 10.1007/s00360-009-0392-y.

Baderan DWK, Hamidun MS, Farid SM. 2019. The abundance, diversity, and the density of mollusks in Tutuwoto Mangrove Area of Anggrek District, North Gorontalo Regency, Gorontalo, Indonesia. GeoEco J 5 (1): 43-54. DOI: 10.20961/ge.v5i1.28652.

Bracken MES, Nielsen KJ. 2008. Diversity of intertidal macroalgae increases invertebrate herbivore consumption. Ecology 85 (10): 2828-2836.

Brosnan DM, Crumrine LL. 1994. Effects of human trampling on marine rocky shore communities. J Exp Mar Biol Ecol 177 (1): 79-97. DOI: 10.1016/0022-0981(94)90145-7.

Cappenberg HAW, Widyastuti E, Dharmawan IWE. 2021. Struktur komunitas dan kepadatan Moluska dan Krustasea di ekosistem mangrove, Kabupaten Merauke, Papua. Jurnal Ilmu dan Teknologi Kelautan Tropis 13: 497-517. DOI: 10.29244/jitkt.v13i3.35132. [Indonesian]

Cernohorsky WO. 1984. Systematics of the family Nassariidae (Mollusca: Gastropoda). In: Bulletin of the Auckland Institute and Museum 14. N.Z Auckland Institute and Museum, Auckland.

Christie P, White A, Deguit E. 2005. Starting point or solution? Community-based marine protected areas in the Philippines. J Environ Manag 66 (4): 441-454. DOI: 10.1006/jema.2002.0595.

Cribb R, Ford M. 2009. Indonesia as an archipelago: Managing islands, managing the seas. In: Cribb R, Ford M (eds). Indonesia beyond the Water's Edge: Managing an Archipelagic State. Books and Monographs. ISEAS-Yusof Ishak Institute, Singapore.

da R. Souza SMA, Matthews-Cascon H, da CG Couto E. 2020. Taxonomic and functional diversity of mollusk assemblages in a tropical rocky intertidal zone. Iheringia Sér Zool 110: e2020027. DOI: 10.1590/1678-4766e2020027.

Dame RF. 1996. Ecology of Marine Bivalves: An Ecosystem Approach. CRC Press, Boca Raton.

Davenport J, Ezgeta-Balić D, Peharda M, Skejić S, Ninčević-Gladan Ž, Matijević S. 2011. Size-differential feeding in *Pinna nobilis* L. (Mollusca: Bivalvia): Exploitation of detritus, phytoplankton and zooplankton. Estuar Coast Shelf Sci 92 (2): 246-254. DOI: 10.1016/j.ecss.2010.12.033.

Denny MW, Gaines SD. 2007. Encyclopedia of Tidepools and Rocky Shores. University of California Press, Berkeley, California, Amerika.

Fairweather PG, Underwood AJ. 1983. The apparent diet of predators and biases due to different handling times of their prey. Oecologia 56 (2-3): 169-179. DOI: 10.1007/BF00379688.

Ginantra IK, Muksin IK, Suaskara IBM, Joni M. 2023. Diversity and distribution of mollusks at three zones of mangrove in Pejarakan, Bali, Indonesia. Biodiversitas 21: 4636-4643. DOI: 10.13057/biodiv/d211023.

Gosling E. 2003. Bivalve Molluscs: Biology, Ecology and Culture. Blackwell Publishing Ltd., Oxford, United Kingdom.

Gratwicke B, Speight MR. 2005. The relationship between fish species richness, abundance and habitat complexity in a range of shallow tropical marine habitats. J Fish Biol 66 (3): 650-667. DOI: 10.1111/j.0022-1112.2005.00629.x.

Gray JS. 2002. Species richness of marine soft sediments. Mar Ecol Prog Ser 244: 285-297. DOI: 10.3354/meps244285.

Hadiyanto H, Prince J, Hovey RK. 2023. Latitudinal biodiversity gradients of rocky intertidal assemblages: Spatial scales and complex associations with environmental factors. Mar Ecol 45: e12789. DOI: 10.1111/maec.12789.

Harley CDG, Hughes AR, Hultgren KM, Miner BG, Sorte CJB, Thornber CS, Rodriguez LF, Tomanek L, Williams SL. 2006. The impacts of climate change in coastal marine systems. Ecol Lett 9 (2): 228-241. DOI: 10.1111/j.1461-0248.2005.00871.x.

Hayati SN. 2018. Pengembangan Pantai Ngrawah sebagai daya tarik wisata baru di Gunungkidul Yogyakarta. [Thesis]. Sekolah Tinggi Pariwisata Ambarrukmo (STIPRAM), Yogyakarta. [Indonesian]

Hidayah N. 2019. Pemasaran Destinasi Wisata. Alfabeta, Bandung. [Indonesian]

Ismaini L, Masfiro L, Rustandi, Dadang S. 2015. Analisis komposisi dan keanekaragaman tumbuhan di Gunung Dempo, Sumatera Selatan. In: Seminar Nasional Masyarakat Biodiversitas Indonesia. Universitas Sebelas Maret, Indonesia. [Indonesian]

Isnaningsih NR, Patria MP. 2018. Peran komunitas Moluska dalam mendukung fungsi kawasan mangrove di Tanjung Lesung, Pandeglang, Banten. Biotropika: J Trop Biol 6 (2): 35-44. DOI: 10.21776/ub.biotropika.2018.006.02.01. [Indonesian]

Kalay DE, Lewerissa YA. 2022. Dominansi sedimen dasar hubungannya dengan kepadatan Gastropoda dan Bivalvia di Perairan Pantai Tawiri Pulau Ambon. Triton: Jurnal Manajemen Sumberdaya Perairan 18 (1): 28-37. DOI: 10.30598/tritonvol18issue1page28-37. [Indonesian]

Kano Y, Chiba S, Kase T. 2001. Major adaptive radiation in neritopsine gastropods estimated from 28S rRNA sequences and fossil records. Proc Biol Sci 269 (1508): 2457-2465. DOI: 10.1098/rspb.2002.2178.

Kay EA, Palumbi SR. 1987. Endemism and evolution in Hawaiian marine invertebrates. Trends Ecol Evol 2 (7): 183-186. DOI: 10.1016/0169-5347(87)90017-6.

Kusumayudha SB, Setiawan J, Ciptahening AN, Septianta PD. 2015. Geomorphologic model of Gunungsewu Karst, Gunung Kidul Regency, Yogyakarta Special Territory, Indonesia: The role of lithologic variation and geologic structure. J Geol Resour Eng 3 (1): 1-8. DOI: 10.17265/2328-2193/2015.01.001.

Levinton JS. 2001. Marine Biology: Function, Biodiversity, Ecology. Oxford University Press, New York.

Little C, Kitching JA. 1996. The Biology of Rocky Shores. Oxford University Press, New York.

Lubchenco J. 1978. Plant species diversity in a marine intertidal community: Importance of herbivore food preference and algal competitive abilities. Am Nat 112 (983): 23-39.

Matthews TG, Fairweather PG. 2008. In situ growth of *Soletellina alba* (Bivalvia: Psammobiidae) in response to detrital supply and mouth status in a seasonally-closed estuary. Estuar Coast Shelf Sci 78 (1): 145-154. DOI: 10.1016/j.ecss.2007.11.015.

Maura G, Aritonang AB, Helena S. 2021. Komposisi dan distribusi Gastropoda di Desa Bakau Besar Laut Kecamatan Sungai Pinyuh Kabupaten Mempawah. Jurnal Laut Khatulistiwa 4 (2): 6-11. DOI: 10.26418/lkuntan.v4i2.45318. [Indonesian]

McArthur MA, Brooke BP, Przeslawski R, Ryan DA, Lucieer VL, Nichol S, McCallum AW, Mellin C, Cresswell ID, Radke LC. 2010. On the use of abiotic surrogates to describe marine benthic biodiversity. Estuar Coast Shelf Sci 88 (1): 21-32. DOI: 10.1016/j.ecss.2010.03.003.

MolluscaBase. 2023. MolluscaBase. https://www.molluscabase.org [10 June 2025]

Mouillot D, Graham NAJ, Villéger S, Mason NWH, Bellwood DR. 2013. A functional approach reveals community responses to disturbances. Trends Ecol Evol 28 (3): 167-177. DOI: 10.1016/j.tree.2012.10.004.

Mulyadi HA, Lekalette J. 2020. Biodiversitas zooplankton di perairan pesisir Pulau Keffing pada musim peralihan II, Kabupaten Seram Bagian Timur. Jurnal Kelautan Tropis 23 (1): 15-28. DOI: 10.14710/jkt.v23i1.4956.

Newell RIE. 2004. Ecosystem influences of natural and cultivated populations of suspension-feeding bivalve mollusks: A review. J Shellfish Res 23 (1): 51-61.

Paat KYR, Lumuindong F, Kaligis EY, Boneka FB, Losung F, Kambey AD. 2022. Kajian struktur komunitas Moluska di Pantai Reklamasi Teluk Manado. J Pesisir dan Laut Tropis 10 (3): 315-324. DOI: 10.35800/jplt.10.3.2022.55016. [Indonesian]

Paine RT. 1974. Intertidal community structure: Experimental studies on the relationship between a dominant competitor and its principal predator. Oecologia 15 (2): 93-120. DOI: 10.1007/BF00345739.

Petchey OL, Gaston KJ. 2002. Functional diversity (FD), species richness and community composition. Ecol Lett 5 (3): 402-411. DOI: 10.1046/j.1461-0248.2002.00339.x.

Peterson MS, Andres MJ. 2021. Progress on research regarding ecology and biodiversity of coastal fisheries and nektonic species and their habitats within coastal landscapes. Diversity 13 (4): 168. DOI: 10.3390/d13040168.

Petuch EJ, Berschauer DP. 2020. Tropical Marine Mollusks: An Illustrated Biogeographical Guide. CRC Press, Boca Raton. DOI: 10.1201/9781003120070.

Plaimo PE, Wabang IL, Dollu EA, Hendrizal A, Alelang IF. 2022. Observing mollusca benthic diversity to measure the success of the implementation of Mulung culture as an effort to conserve aquatics in the waters of Lapang-Batang Island, Alor Regency, East Nusa Tenggara. IOP Conf Ser: Earth Environ Sci 1118: 012048. DOI: 10.1088/1755-1315/1118/1/012048.

Prasetya JD, Ambariyanto, Supriharyono, Purwanti F. 2017. Mangrove health index as part of sustainable management in mangrove ecosystem at Karimunjawa National Marine Park Indonesia. Adv Sci Lett 23 (4): 3277-3282. DOI: 10.1166/asl.2017.9155.

Prasetya TA, Nazira FK, Millaty INK, Zulfikar WG, Nazara FA, Trijoko T. 2017. Short Communication: Molluscan diversity (Gastropoda: Neogastropoda) in the intertidal zone of Nguyahan Beach, Gunungkidul, Yogyakarta, Indonesia. Ocean Life 1 (2): 55-60. DOI: 10.13057/oceanlife/o010203.

Pratiwi MA, Ernawati NM. 2016. Analysis of water quality and mollusk density in the mangrove ecosystem area, Nusa Lembongan. J Mar Aquat Sci 2 (2): 67-72. DOI: 10.24843/jmas.2016.v2.i02.67-72.

Priyono B, Abdullah M. 2013. Keanekaragaman jenis kupu-kupu di Taman Kehati Unnes. Biosaintifika: J Biol Biol Educ 5 (2): 100-105. DOI: 10.15294/biosaintifika.v5i2.2749. [Indonesian]

Putra WPES, Santoso D, Syukur A. 2021. Keanekaragaman dan pola sebaran Moluska (Gastropoda dan Bivalvia) yang berasosiasi pada ekosistem mangrove di Pesisir Selatan Lombok Timur. Jurnal Sains Teknologi Lingkungan 25 (2): 223-242. DOI: 10.29303/jstl.v0i0.274.

Rahmawati YF, Putri RA, Prakarsa TBP, Muflihaini MA, Aliyani YP. 2021. Diversity and distribution of molluscs in the intertidal zone of Nglambor Beach, Gunung Kidul, Yogyakarta. Bio Web Conf 33 (5): 01002. DOI: 10.1051/bioconf/20213301002.

Reyes M, San Diego-Mcglone M, Pavia R, Opiňa J, Isah R, Magyaya R, Morris J, Tamayo N, Licuanan W. 2020. Low pH and low coral cover at a shallow hydrothermal vent site in Batangas, Philippines. Philipp J Sci 151 (2): 665-670. DOI: 10.56899/151.02.09.

Riantoby EESR, Paulus CA, Al Ayubi A. 2021. Kajian jenis, kepadatan dan keanekaragaman makrozoobentos di Oesapa Barat, Kota Kupang. Jurnal Bahari Papadak 2 (2): 12-21. [Indonesian]

Rosenberg G. 2014. A new critical estimate of named species-level diversity of the recent mollusca. Am Malacol Bull 32 (2): 308-322. DOI: 10.4003/006.032.0204.

Setiawan A. 2022. Keanekaragaman hayati Indonesia: Masalah dan upaya konservasinya. Indones J Conserv 11 (1): 13-21. DOI: 10.15294/ijc.v11i1.34532. [Indonesian]

Setiawan R, Sudarmadji, Mulyadi BP, Hamdani RH. 2019. Preferensi Habitat Spesies Kerang Laut (Moluska: Bivalvia) di Ekosistem Intertidal Tanjung Bilik Taman Nasional Baluran. Nat Sci J Sci Technol 8 (3): 165-170. DOI: 10.22487/25411969.2019.v8.i3.14601.

Sitompul MK. 2020. Identifikasi keanekaragaman jenis-jenis kerang (Bivalvia) daerah pasang surut di perairan Desa Teluk Bakau. J Manajemen Riset dan Teknologi 2 (1): 42-51. [Indonesian]

Subhan, Anhar A, Muslih AM, Ar-Rasyid UH, Maimunah S, Nasution AA. 2022. Urban forest carbon stock and biodiversity assesment at Nagan Raya Regency. IOP Conf Ser: Earth Environ Sci 951: 012071. DOI: 10.1088/1755-1315/951/1/012071.

Sudarsono H, Susantun I. 2019. Pengembangan potensi wisata di kawasan Pantai Selatan Kabupaten Gunung Kidul, Yogyakarta. Agriekonomika 8 (1): 81. DOI: 10.21107/agriekonomika.v8i1.5011. [Indonesian]

Sulistyani TH, Rahayuningsih M, Partaya. 2014. Keanekaragaman jenis kupu-kupu (Lepidoptera:Rhopalocera) di Cagar Alam Ulolanang Kecubung Kabupaten Batang. Life Sci 3 (1): 9-17. [Indonesian]

Tan SK, Clements R. 2008. Taxonomy and distribution of the Neritidae (Mollusca: Gastropoda) in Singapore. Zool Stud 47: 481-494.

Taylor JD. 1984. A partial food web involving predatory gastropods on a Pacific fringing reef. J Exp Mar Biol Ecol 74 (3): 273-290. DOI: 10.1016/0022-0981(84)90130-8.

Umanailo MCB, Apriyanto M, Lionardo A, Kurniawan R, Amanto BS, Rumaolat W. 2021. Community structure and social actions in action of land conversion. Front Environ Sci 9: 701657. DOI: 10.3389/fenvs.2021.701657.

Underwood AJ, Chapman MG. 1996. Scales of spatial patterns of distribution of intertidal invertebrates. Oecologia 107 (2): 212-224. DOI: 10.1007/BF00327905.

Van der Schatte Olivier A, Jones L, Le Vay L, Christie M, Wilson J, Malham SK. 2018. A global review of the ecosystem services provided by bivalve aquaculture. Rev Aquac 12: 3-25. DOI: 10.1111/raq.12301.

Wahyuni I, Sari IJ, Ekanara B. 2017. Biodiversitas mollusca (Gastropoda dan Bivalvia) sebagai bioindikator kualitas perairan di kawasan Pesisir Pulau Tunda, Banten. Jurnal biodidaktika 12 (2): 45-56. DOI: 10.30870/biodidaktika.v12i2. [Indonesian]

Walters JS, Maragos J, Siar S, White AT. 1998. Participatory coastal resource assessment: A handbook for community workers and coastal resource managers. Coastal Resource Management Project and Silliman University, Cebu City, Philippines.

WoRMS [World Register of Marine Species]. 2024. https://www.marinespecies.org [10 June 2025]

Zusron M, Wibowo CA, Langgeng A, Firdausi FM, Etfanti S. 2013. Biodiversity of mollusks at Ela-Ela Beach, Sekotong Lombok Barat Indonesia. KnE Life Sci 2: 574-578. DOI: 10.18502/kls.v2i1.219.