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Marine Macroinvertebrate Biodiversity in Ecotourism of Pangandaran Coastal, Indonesia

Asep Sahidin[1, 2]*, Vira Lestari[2], Irfan Zidni[1], Pringgo Kusuma Dwi Noor Yadi Putra[1, 3], Faqih Baihaqi[1], Lady A. Sriwijayanti[1, 3], Zahidah[1]

[1]Department of Fisheries, Faculty of Fisheries and Marine Science, Universitas Padjadjaran. Jatinangor, Sumedang, West Java, Indonesia
[2]Laboratory of Aquatic Resources, Faculty of Fisheries and Marine Science, Universitas Padjadjaran. Jatinangor, Sumedang, West Java, Indonesia
[3]Tropical Marine Fisheries Study Program, Pangandaran Campus, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran

***Corresponding Author: asep.sahidin@unpad.ac.id**

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ABSTRACT

The Pangandaran coast, recognized for its diverse substrates, is a popular destination for marine tourism. The characteristics of the substrate and the activities linked to tourism can significantly influence aquatic organism communities. The present study investigated the biodiversity and distribution of marine macroinvertebrate in the ecotourism coastal of Pangandaran, Indonesia. Marine macroinvertebrates investigation was conducted using survey method with a quadrant transect from low to high tide in eight intertidal zone of Pangandaran coastline. Pangandaran coastline hosts 160 marine macroinvertebrate species divided into thirteen classes and seven phyla. The mollusk phylum exhibits the greatest diversity with 99 species, whereas Cnidaria follows with 8 species. The distribution pattern of marine invertebrates in the Pangandaran coast is categorized into four clusters: the rocky ecosystem (Karapyak, Pasir Putih, and Madasari), the muddy ecosystem (Nusawiru and Muara Cijulang), the sandy ecosystem (Pantai Barat), and the craggy ecosystem (Karang Nini and Batu Hiu). In the intertidal zone of rocky substrates (3.99–5.08), there were more diversity of marine macroinvertebrates than on muddy, sandy, and craggy surfaces (0.65-2.16, 0.65, and 0.50-0.80, respectively). *Cerithium breviculum*, *Thais jubilaea*, and *Anthopleura elegantissima* predominated the rocky ground. *Faunus ater*, *Terebia* sp., and *Clithon oualaniensis* predominated the muddy ground. Conversely, the sand substrate contained solely the gastropod *Hastula bacillus*. Concurrently, *Clibanarius vittatus*, a worldwide crustacean species, flourishes across various substrate types, demonstrating a density of 69 to 15 ind.m^{-2}. The analysis of geographical distribution indicates that substrate type and tourism activity significantly influence the distribution of invertebrates in the Pangandaran coastal area.

INTRODUCTION

Ecologically, the intertidal zone is the narrowest part of the oceans, covering merely a few meters between high and low tides. Despite its narrow expanse, the

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intertidal zone exhibits substantial biodiversity **(Patovic *et al.*, 2017; Hamza *et al.*, 2018; Palomo *et al.*, 2019)** owing to its function as a habitat for many marine organisms, providing feeding, nursery, and spawning grounds **(Sahidin *et al.*, 2018a; Palomo *et al.*, 2019)**. Macroinvertebrate organisms associate directly with the intertidal zone, such as mollusks, crustaceans, polychaetes, oligochaetes, and echinoderms. Macroinvertebrates are crucial to the marine ecosystem as they directly influence the pollutant metabolism **(van Loon *et al.*, 2015; Sahidin *et al.*, 2018b; Mearns *et al.*, 2019)**, nutrient cycle **(Hale *et al.*, 2016; Griffiths *et al.*, 2017)**, and secondary productivity within the benthic ecosystem **(Bissoli & Bernardino, 2018)**. The distribution of macroinvertebrates is affected by water depth, temperature, salinity, and substrate type **(Gholizadeh *et al.*, 2012; Sahidin *et al.*, 2014)**. Fluctuations in distribution and abundance are crucial in ecological and environmental management **(Harris, 2012)** since they contribute to preserving the biological diversity, ecosystem stability, and prosperity **(Kartika & Mu, 2014)**.

Currently, macroinvertebrate diversity declines because of many anthropogenic activities in the intertidal zone, including housing construction, fishing, inland river pollution, and tourism. These activities directly affect macroinvertebrates since their mobility within the benthic ecosystem is limited **(Sahidin *et al.*, 2019)**. Prior research has associated declines in macroinvertebrate populations with sedimentation and economic exploitation, encompassing food, jewelry, decorations, specimens, and pharmaceuticals **(Leal *et al.*, 2012; Torres *et al.*, 2017; Wardiatno *et al.*, 2017; Sahidin *et al.*, 2018b; Sharma *et al.*, 2018)**. The ornament trade endangers the survival of marine macroinvertebrates, particularly mollusks, which are the most commercially traded phylum in nations including Papua New Guinea, Switzerland, and Mexico **(Garza *et al.*, 2012; Biondo, 2017; Militz *et al.*, 2018)**. Moreover, invertebrate ornaments are a traded commodity in Indonesian coastal ecotourism, specifically in Sulawesi **(Ferse *et al.*, 2013)**, Bali **(Nijman *et al.*, 2015; Nijman & Lee, 2016)**, Pangandaran **(Nijman *et al.*, 2016)**, and Jakarta **(Cappenberg, 2017)**. Literature review shows the lack of comprehensive data on macroinvertebrate diversity and distribution in the Pangandaran area, which hinders effective biodiversity management. However, it is necessary to add information on the level of macroinvertebrate utilization by the community for commercial and hobby purposes.

Furthermore, the Pangandaran intertidal zone comprises eight ecotourism coastal destinations: Karapyak, Karang Nini, Pasir Putih, Pantai Barat, Batu Hiu, Muara Cijulang, Nusa Wiru, and Madasari. These coastal areas have different substrates, including rocky, coral, sandy, and muddy substrates **(Sahidin *et al.*, 2018)**. Annual tourist numbers to Pangandaran ecotourism are on the rise. In 2018, the Pangandaran coast had 2,020,106 visitors, comprising 1,312 international tourists and 2,018,794 domestic tourists **(Pangandaran Regency Tourism and Culture Office, 2018)**. The tourist activities substantially affect the coastal ecology of Pangandaran. Although tourism provides advantages to the community, it simultaneously harms the ecosystems and marine animals. The macroinvertebrate data in Pangandaran lack adequate information regarding species, spatial distribution, and the fundamental biology of invertebrate records in scientific literature. Consequently, future biodiversity management necessitates research on diversity, distribution, and current marine invertebrate data. The mian objective of this study was to update the biodiversity of marine macroinvertebrates, covering inventories of diversity and geographical distribution throughout the touristic coast of Pangandaran.

MATERIALS AND METHODS

Study area and macroinvertebrates collection

This study was conducted by the monthly survey from eight intertidal zones of Pangandaran coastal ecotourism, with three replicates in each location (Fig. 1 & Table 1). Macroinvertebrate samples were collected using a line transect 1x1m square and collected manually by hand. We meticulously scrutinized every quadrant until we discovered no more macroinvertebrates. We counted the number of samples in each quadrant for density data, thereafter, returning them to their habitat and photographing (dorsal and ventral) specific species for identification. The sample was identified using manual book identification and scientific papers of Echinodermata **(Lee & Shin, 1996)**, Mollusks **(Dharma 2005, Sahidin 2019)**, Crustacea **(Chertoprud *et al.*, 2010)**, Polychaeta **(Al Omari 2011; Sahidin *et al.*, 2016)**, and nomenclature names written by the *World Register of Marine Species* (WoRMS: http://www.marinespecies.org/index.php) and http://species-identification.org.

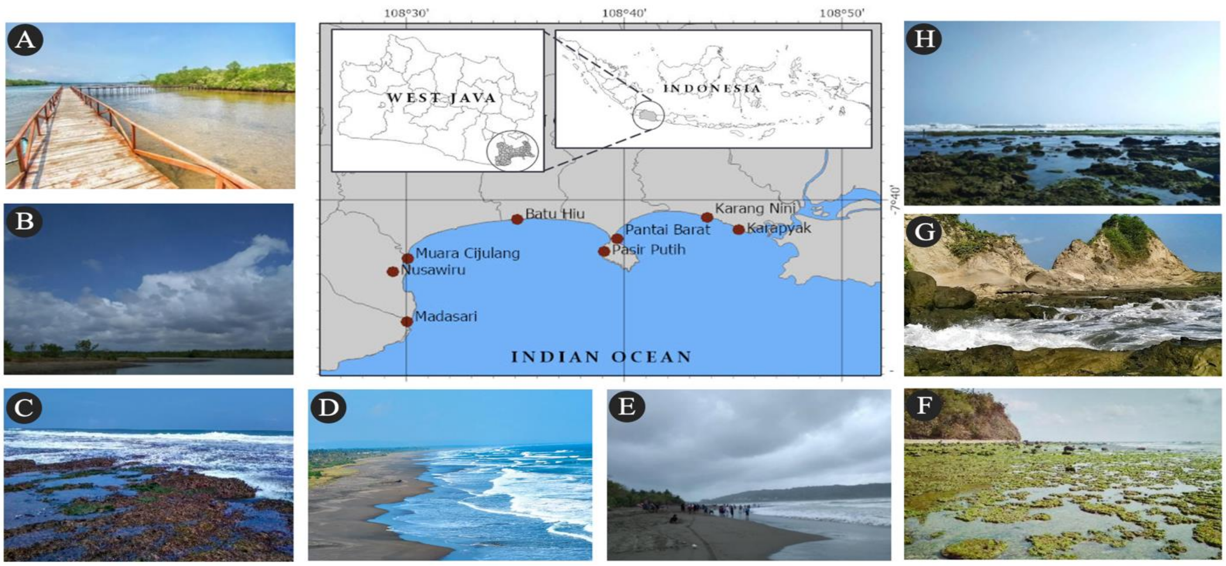

Fig. 1. Sampling sites in ecotourism of Pangandaran coastal: **A)** Muara Cijulang, **B)** Nusawiru, **C)** Madasari, **D)** Batu Hiu, **E)** Pantai Barat, **F)** Pasir Putih, **G)** Karang Nini, **H)** Karapyak

Table 1. Coordinate and characteristic of sites sampling

No	Sampling site	Coordinates		Substrate and vegetation
		Latitude	Longitude	
1	Karapyak	-7⁰42'31.6"	108⁰45'11.9"	rock, coral, stone, sandy-mud, seagrass, macroalgae
2	Karang Nini	-7⁰41'31.0"	108⁰43'45.0"	big rock, not vegetation
3	Pasir Putih	-7⁰42'47.0"	108⁰39'05.0"	a big rock, sand, macroalgae, seagrass
4	Pantai Barat	-7⁰42'06.0"	108⁰39'41.0"	fine sand, not vegetation
5	Batu Hiu	-7⁰45'23.1"	108⁰35'29.0"	big rock, not vegetation
6	Muara Cijulang	-7⁰43'10.1"	108⁰30'04.0"	muddy-sand, mangrove
7	Nusawiru	-7⁰43'23.0"	108⁰29'32.7"	muddy, mangrove
8	Madasari coastal	-7⁰46'35.0"	108⁰30'02.0"	big rock, stone, macroalgae, seagrass

Community structure determination of marine invertebrates

The composition of marine invertebrates was estimated by the theoretical formula $Kj = (ni/\sum n)x100\%$, where *Kj* represents relative composition; *ni* is total individuals; and Σn is total species that were found. While the density was estimated following the formula $D = ni/A$, where *D* represents density (ind/m^2), *ni* is the number of individuals of one species, and *A* is sampling area. The diversity of marine invertebrates was estimated using the Shannon-Weaner formula $H' = -\sum((ni/N)xLog2(ni/N))$, where *H'* represents Shannon-Weaner diversity index; *ni/N* is species proportion i from total species; *ni* is total individual of each species; and *N* is total individual. In addition, the evenness index was calculated using the formula E = H'/lnS, where E represents the evenness index; H' is the diversity index; and S is the total number of species found.

Data analysis

The Kruskal-Wallis test and a post hoc pairwise Mann-Whitney U test were used to compare the community structure (density, diversity, uniformity, and covering index) between different locations and macroalgae classes. Spatial analysis was used to determine the distribution and relationship between environmental variables and macroalgae using the multidimensional scaling (MDS) method. All analyses were conducted using R-Studio, an open-source software, using codes sourced from **Albert and Rizzo (2012)**, **Chang (2013)** and **Long and Teetor (2019)**.

RESULTS

Species riches, density, and diversity

This study documented 8,810 marine invertebrate individuals, classified into 160 species across 13 classes and 7 phyla (Figs. 2, 4 & Table 2). Mollusca was the most numerous group of species recorded, with the highest species proportion at 118 species, reflecting 68.6% of the total macroinvertebrates found, followed by Cnidaria, Echinoderm, Arthropod, Annelid, and Porifera (Fig. 2). The Gastropod class showed dominance with 98 species, accounting for 58.1% of the total species, followed by Bivalve, Anthozoa from Cnidaria, Malacostraca from Arthropoda, and Polychaeta from Annelida, with 16, 10, 9, and 7 species, respectively (Fig. 2). In the Echinoderm group, there were five species of Ophiuroidea, four species of Echinoidea, and one species of Holothuroidea (Fig. 2), along with other less represented groups such as Cephalopoda from Mollusca, Scyphozoa and Hydrozoa from Cnidaria, Demospongia from Porifera, and Plidiopora (Fig. 2).

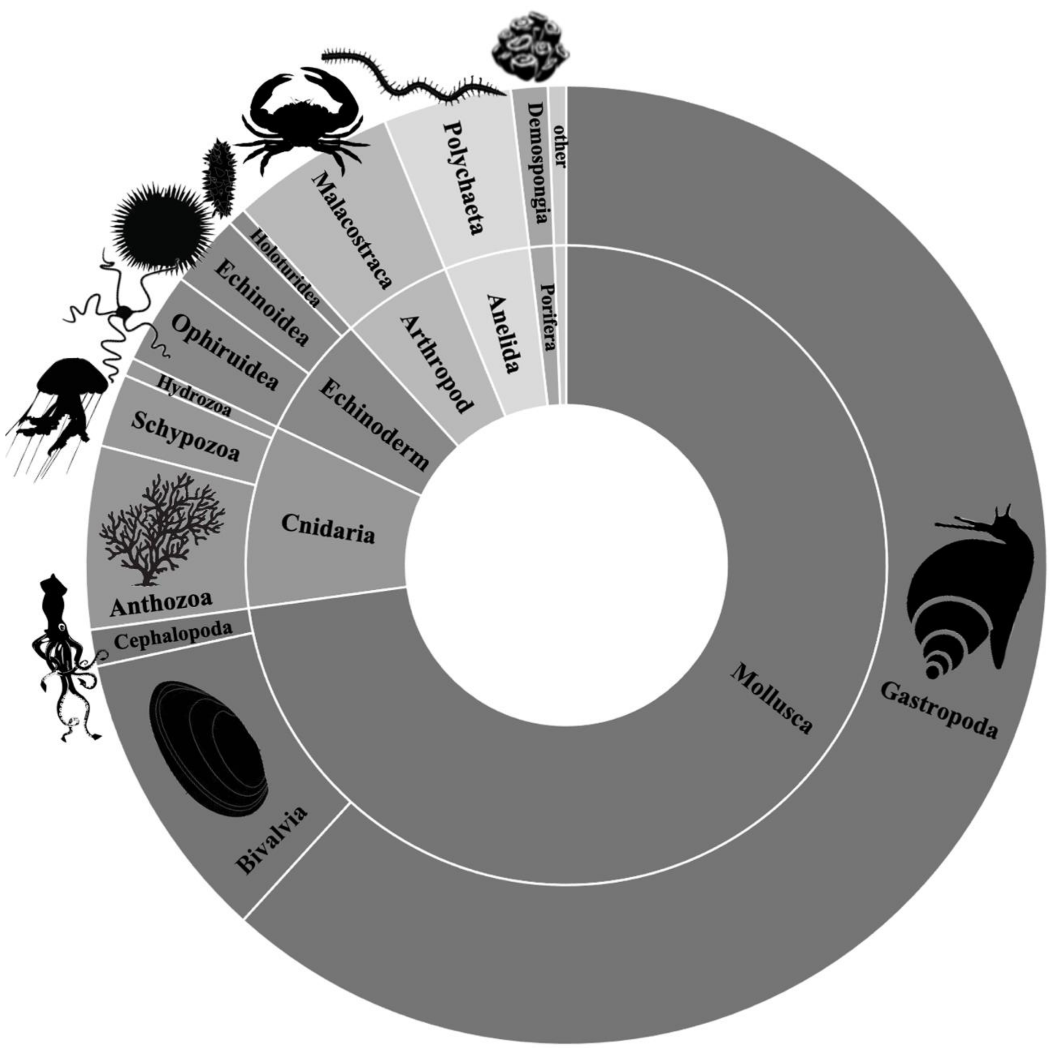

Fig. 2. Composition of macroinvertebrates from eight locations in Pangandran coast

Habitats combined with rock, coral, stone, sandy-mud, seagrass, and macroalgae in the Karapyak, Pasir Putih, and Madasari sites were recorded with the highest in species richness (93, 87, and 72 species, respectively) (Fig. 3A) regarding the total species. On the other hand, Muara Cijulang had the highest abundance (342 ind.m^{-2}) (Table 1), followed by Nusawiru, Karapyak, and Madasari (230, 191, and 126 ind.m-2, respectively) (Fig. 2), while Batu Hiu had the lowest abundance (14 ind.m^{-2}) (Fig. 2). The number of Gastropod taxa in the Karapyak and Madasari sites were highest (65, 43 species, respectively) but middle in abundance (200 ind.m^{-2}) (Fig. 3). In contrast, the number of Gastropod taxa at the Nusawiru and Muara Cijulang sites was low but high in abundance (303, 521 ind.m^{-2}, respectively) (Fig. 3). In addition, the Anthozoa class exhibited high abundance at the Karapyak and Madasari sites, with 497 and 329 individuals per square meter, respectively (Fig. 3), though it had a low number of taxa. *Anthopleura elegantissima* dominated the Karapyak and Madasari locations, while *Faunus ater* was dominant in the Nusawiru and Muara Cijulang locations (Table 1).

The biological indices of the Shannon-Wiener diversity index showed that the Karapyak, Pasir Putih, and Madasari sites were included in the high diversity category (5.08, 3.99, and 4.52, respectively) (Fig. 2B), while the Muara Cijulang and Nusawiru locations were included in the medium diversity category (2.17 and 2.03, respectively) (Fig. 2B). In contrast, the Karang Nini, Batu Hiu, and Pantai Barat sites were included in the low diversity category (0.80 and 0.65, respectively) (Fig. 2B). In contrast, the evenness index showed no significant difference in all locations (P> 0.05) (Fig. 3C). The cosmopolitan macroinvertebrate species, *Cerithium punctatum, Clypeomorus bifasciata, Clypeomorus petrosa Engina mendicaria, Mitra paupercula, Morula granulata, Plakobranchus ocellatus,* and *Thais tuberosa* (gastropod), and *Clibanarius vitarus*, *Grapsus,* and *Ophiocoma scolopendrin* (Echinodermata), were found in all locations (Table 2).

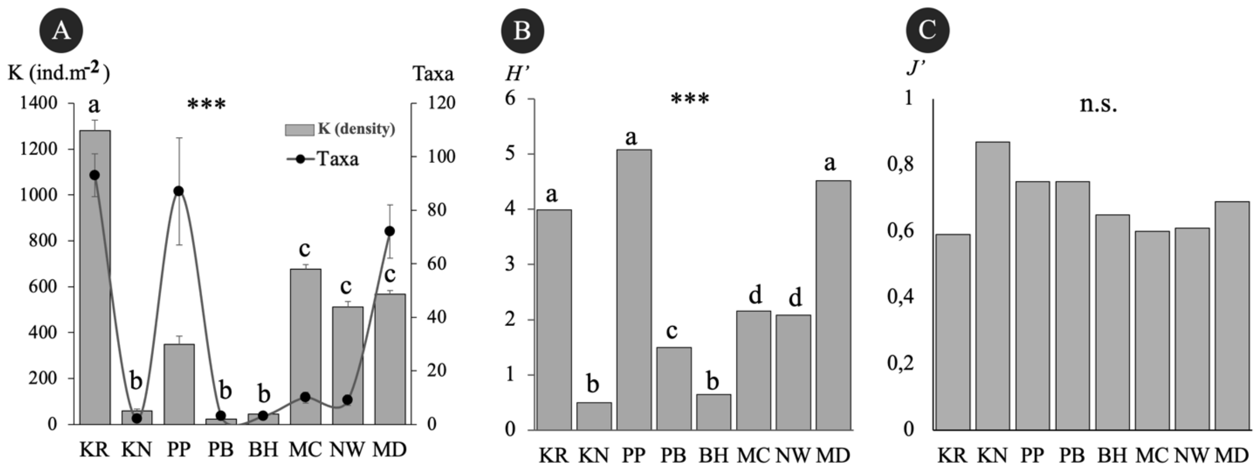

Fig. 3. Marine macroinvertebrate community structure in ecotourism of Pangandaran coastal: **A)** Numbers of species (taxa) and density (K), **B)** diversity index (*H'*), and **C)** evenness index (*J'*). Sampling sites: KR (Karapyak), KN (Karang Nini), PP (Pasir Putih), PB (Batu Hiu), MC (Muara Cijulang), NW (Nusawiru), and MD (Madasari). P-value of Kruskal-Wallis test (*** P <0.001; n.s.= no significant different P >0.05). The post hoc Mann-Whitney U test; significant differences (P<0.05) are labeled with superscript alphabets a, b, and c.

Table 2. Species list and distribution pattern of marine macroinvertebrate in Pangandaran coast

Phylum to class	Sampling sites								Habitat
Species	KR	KN	PP	PB	BH	MC	NW	MD	
MOLLUSCS									
Gastropod									
Conus sponsalis Hwass in Bruguière, 1792	+		+						R, S
Conus chaldaeus Roding, 1798	+		+					+	R, S
Conus coffeae Gmelin, 1791			+						R, S
Conus lividus Hwass in Bruguière, 1792	+		+						R, S
Conus infinitus Rolan, E.M., 1990			+						R, S
Conus ebraeus Linnaeus, 1758	+		+					+	R, S
Conus retifer Menke, 1829			+						R, S
Conus miles Linnaeus, 1758	+		+						R, S
Conus textile panniculus Linnaeus, 1758	+								R, S
Conus miliaris Hwass in Bruguière, 1792	+								R, S
Conus coronatus Gmelin, 1791								+	R, S
Cypraea tigris Linnaeus, 1758	+							+	R, S
Cypraea eglantina Duclos, 1833	+								R, S
Cypraea lynx Linnaeus, 1758	+								R, S
Cypraea annulus Linnaeus, 1758	+		+					+	R, S
Cypraea depressa Gray, 1824			+						R, S
Cypraea talpa Linnaeus, 1758	+							+	R
Cypraea minoridens Melvill,1901	+							+	R
Cypraea gracilis gracilis Gaskoin, 1849			+						R,
Cypraea ursellus Gmelin, 1791			+						R, S
Cypraea interrupta Gray, 1824	+								R, S
Trivia oryza Lamarck, 1811	+								R, S
Strombus mutabilis Swainson, 1821			+						S
Lambis chiragra chiragra Linnaeus, 1758	+								SM
Pyrene sp.	+		+						R
Pardalinops testudinaria Link,1807	+		+						R
Pyrene testudinaria Link,1807	+		+						R
Pyrene fasciata Sowerby, 1825	+		+						R
Anachis terpsichore Sowerby, 1822	+		+					+	R
Euplica sp.	+							+	St
Euplica scripta Lamarck, 1822	+		+						S
Anazola lutaria Roding, 1798	+		+						S
Olive athenia Duclos, 1840	+		+					+	S
Volvarina sp.	+		+						S
Hastula bacillus Deshayes, 1859				+					S
Turritella terbra Linnaeus, 1758	+		+						S, M

Faunus ater Linnaeus, 1758			+++	+++		S, M
Epitonium aculeatum Sowerby, 1844	+	+			+	R
Tarebia sp.				+++		M
Melanoides maculata Born, 1778				+		M
Cerithidea cingulata Gmelin, 1791	+				+	SM
Cerithidea weyersi Dautzenberg,1899	+					SM
Terebralia sulcata Born, 1778			+			S, M
Chicoreus torrefactus Sowerby, 1841	+	+				R, S
Chicoreus alabaster Reeve, 1845		+				R, S
Thais jubilaea Tan & Sigurdsson, 1990	++	+			+	R, S
Morula granulata Duclos, 1832	+	+			+	R, S
Morula marginalba Blainville, 1832	+				+	R, S
Semiricinula muricoides Blainville, 1832	+	+			+	R, S
Ergalatax margariticola Broderip, 1833	+	+				R, S
Orania dharmai Houart,1944	+	+			+	R, S
Drupella cornus Roding, 1798	+	+			+	R, S
Cerihium sp.	++	+			+	R, S
Cerithium breviculum Sowerby, 1834	+++	+			++	R, S, SM
Cerithium coralium Kiener, 1841	+	+			+	R, S
Cerithium kobelti Dunker,1877			+++			R, S
Clypeomorus sp.	++	+			+	R, S
Clypeomorus petrosa W. wood, *1828*	+	+			+	R, S
Rhinoclavis sinensis Gmelin, 1791	+	+			+	R, S
Cantharus undosus Roding, 1798	+	+			+	R, S
Engina zonalis Lamarck, 1822	+				+	R, S
Engina mendicaria Linnaeus, 1758	+	+				St, R
Engina alveolata Kiener, 1836		+				St, S
Gyrineum natator Roding, 1798	+	+				St, S
Cymatium rubeculum Linnaeus, 1758	+				+	R, S
Latirus craticulatus Linnaeus, 1758	+					R, S
Trochus stellatus Gmelin, 1791	+	+			+	R, S
Trochus radiatus Gmelin, 1791	+	+			+	S
Tectus triserialis Lamarck, 1822		+				R, S
Turbo bruneus Roding, 1798		+			+	R, St, S
Euchelus asper quadrinatus Gmelin, 1791	+	+			+	R, St, S
Euchelus sp Gmelin, 1791	+				+	St
Cellana radiate enneagona Reeve, 1854		+			+	St
Nerita plicata Linnaeus, 1758	+	+			+	St
Nerita albicilla Linnaeus, 1758	+	+			+	S, St
Clithon oualaniensis lesson, 1831			+++	++		S, St
Clithon faba Sowerby, 1825			+	+		S, St
Clithon corona Linnaeus, 1758				+		S, St
Clithon squarrosus Recluz, 1843			+			S, St

Nutica catena da Costa, 1778		+				+	P
Mitra fulvescens Broderip, 1836	+	+				+	R, S
Mitra litterata Lamarck, 1811	+	+				+	R, S
Mitra paupercula Linnaeus, 1758	+	+				+	R, S
Mitra scutulata Gmelin, 1791	+					+	R, S
Mitra pica Dyllwin, 1817	+					+	R, S
Mitra ambigua Swainson, 1829	+	+				+	R, S
Vexillum sp.	+						R, S
Cerotosoma trilobatum	+						R, S
Placobrancus ocelatus	++	++				+	R, S
Bivalvia							
Donax sp.		+	+			+	R, S
Anadara antiquata Linnaeus, 1758	+	+				+	R
Barbatia sp.	+	+				+	R, S
Mytilus pictus Born, 1778		+				+	R, S
Perna viridis Linnaeus, 1758				+			R, S
Ostrea edulis Linnaeus, 1758	+	++				+	R
Saccostrea cucullata Born, 1778				+++	+++		M
Sunetta truncata Deshayes, 1854					+		R
Tridacna gigas Linnaeus, 1758	+	+				+	St, R
Antigona reticulata Linnaeus, 1758	+	+				+	St, R
Polyplacopora							
Conspisious chiton Pilsbry,1892	+					+	R
ECHINODERMATA							
Ophiuroidea							
Ophiothrix fragilis 1 abildgaard,189	+	+					R, S
Ophiothrix fragilis 2 abildgaard,189		+					R, S
Ophiocoma erinaceus Muller & Trochel, 1842	++	++					R, S
Ophiocoma scolopendrina Lamarck 1816	++	++				+	R, S
Echinoidea							
Colobocentrotus atratus Linnaeus, 1758						++	R
Echinometra oblonga blainville, 1825	+	+				++	R
Echinotrix calamaris Pallas, 1774		+					R
Diadema setosum Leske, 1778		+				+	R, S
Holothuroidea							
Holothuria atra Jaeger, 1833	+						R
PORIFERA							
Demospongiae							
Spongia sp.		+					R
Haliclona sp. Grant, 1836	++	+				+	R
CNIDARIA							
Anthozoa							
Heteractis aurora Quoy & Gaimard, 1833	+	+				+	R

Heteractis magnifica Quoy & Gaimard, 1833			+					+	R
Anthopleura elegentissima Brandt 1835	+++		+++					++	R
Aiptasia pulchella Carlgren, 1943	++							+	R
Aiptasia mutabilis Gravenhorst, 1831	++							+	R
Actinia sp.	+		+					+	R
Aiptasia sp.								+	R
Diploria labyrinthiformis Linnaeus, 1758			+						R
Meandrina sp.			+						R
Zoanthus sp.	+++		+					++	R
Hydrozoa									
Physalia physalis Linnaeus, 1758	+								R, S
ANELIDA									
Polychaeta									
Sabellastarte australiensis Haswell, 1884								+	R
Sabellastarte magnifica Shaw, 1800	+								R
Bispira brunnea Treadwell, 1917	+++							+	R
Nereis sp.								+	R, SM
Eunice sp.	+		+						R, M
NEMERTEA									
Plidiophora									
Baseodiscus sp.	+		+					+	R, SM
Baseodiscus hemprichii Ehrenberg, 1831			+						R, SM
ARTHROPODA									
Malacostraca									
Squilla mantis Linnaeus, 1758			+						R
Clibanarius vittatus Bosc 1802	++	+	+	+	+	+	+	+	R, M
Scopimera globosa De Haan, 1835				+					S
Thalamita coeruleipes Hombron & Jackuinot, 1846	+							+	R, S
Thalamita hellerii Hoffmann, 1874	+								R, S
Charybdis riversandersoni Alcock, 1899	+								R, S
Eriphia sebana Shaw & Nodder, 1803	+		+					+	St, R
Grapsus sp.	+		+					+	St, R, S
Leptodius sp.	+		+						R, S
Uca sp.								+	M

Habitats (R: rock, S: sand, SM: sand-muddy, M: muddy, and St: stone), +: low recorded, ++: medium recorded and +++: high recorded, Location (KR: Karapyak, KN: Karang Nini, PP: Pasir Putih, PB: Pantai Barat, BH: Batu Hiu, MC: Muara Cijulang, NW: Nusawiru, MD: Madasari).


Gastropoda
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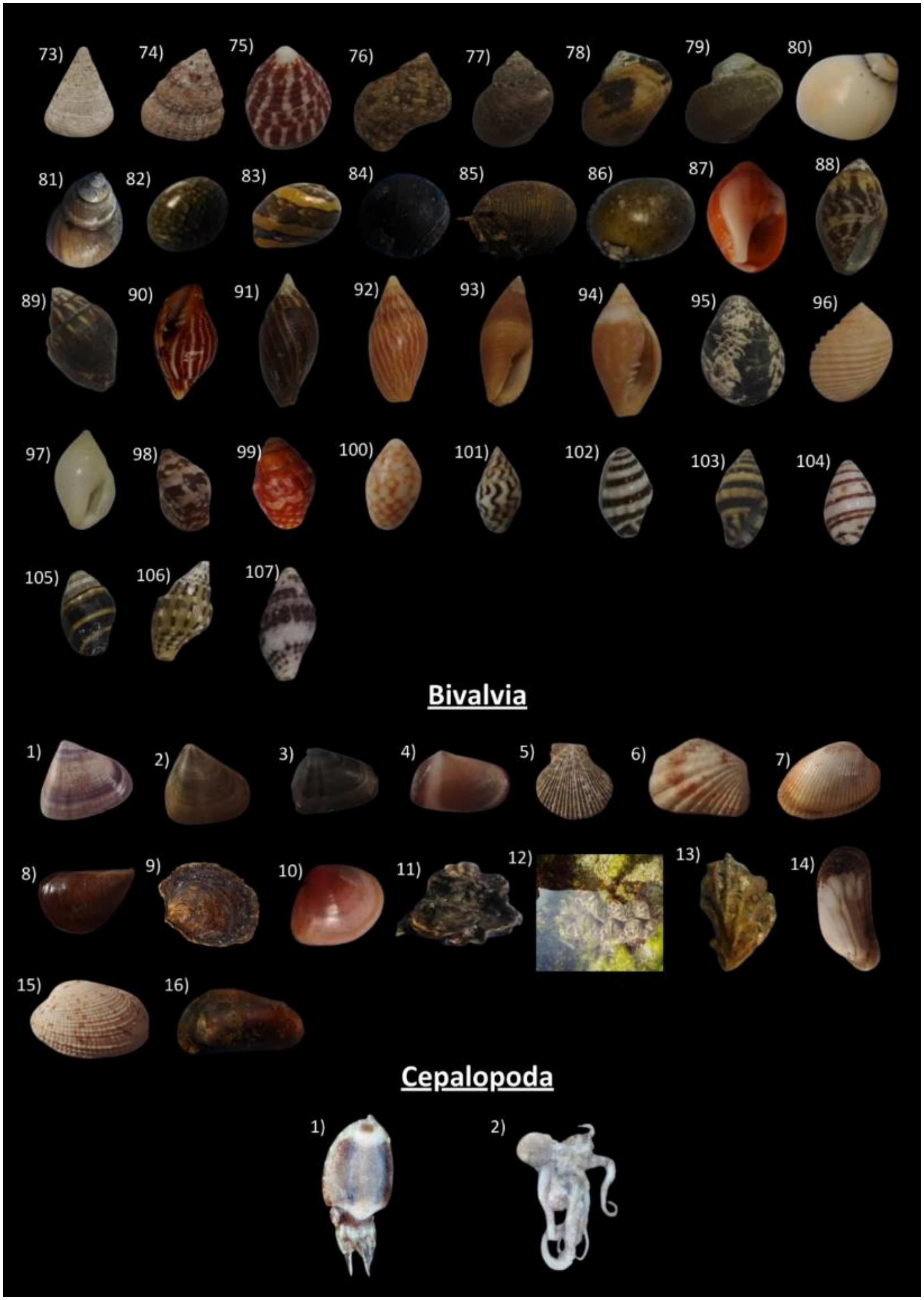
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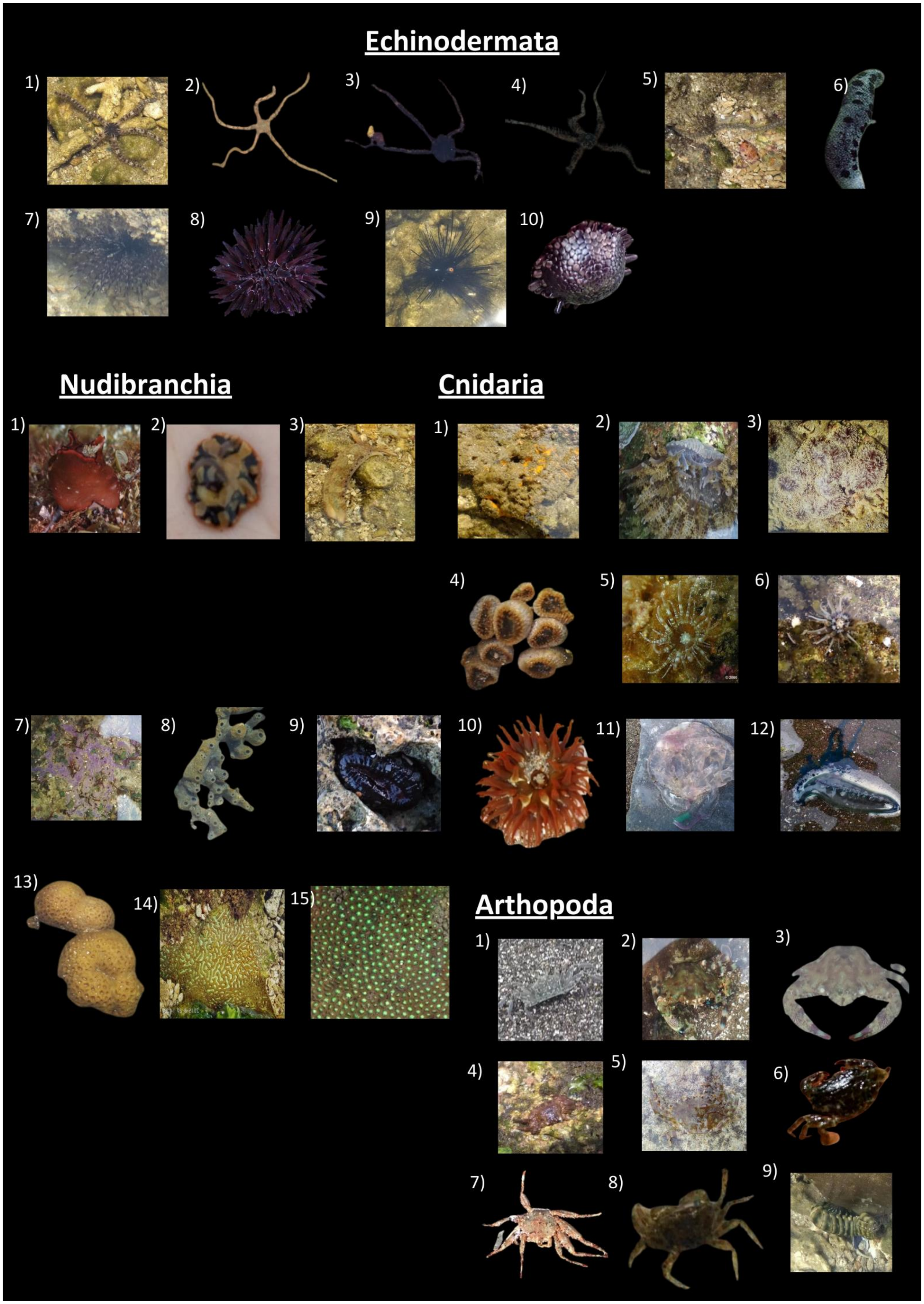
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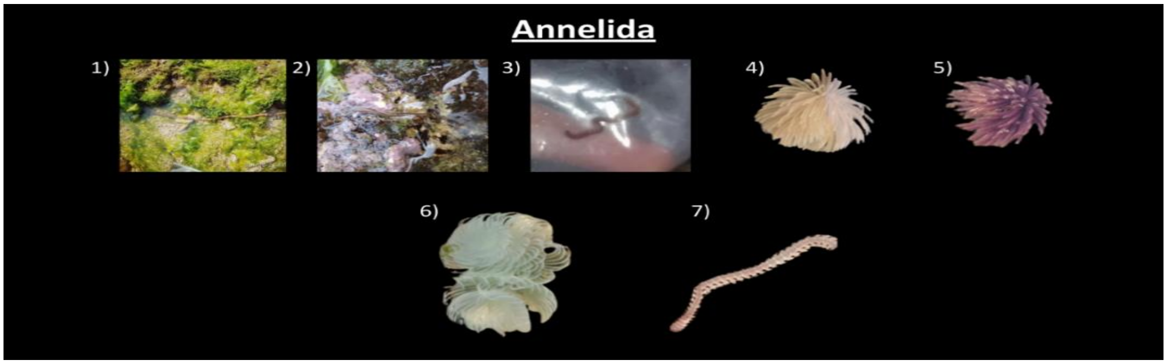

Fig. 4. Gastropoda: (1) *Conus sponsalis*. (2) *Conus chaldaeus*. (3) *Conus ochroleucus*. (4) *Conus coffeae*. (5) *Conus lividus*. (6) *Conus infinitus*. (7) *Conus ebraeus*. (8) *Conus retifer*. (9) *Conus miles*. (10) *Conus coronatus.* (11) *Conus textile*. (12) *Conus miliaris.* (13) *Cypraea tigris*. (14) *Cypraea eglantina.* (15) *Cypraea lynx.* (16) *Cypraea annulus.* (17) *Cypraea depressa.* (18) *Cypraea talpa.* (19) *Cypraea ventriculus.* (20) *Cypraea minoridens.* (21) *Trivia oryza.* (22) *Cypraea gracilis.* (23) *Cypraea ursellus.* (24) *Cypraea interrupta.* (25) *Strombus mutabilis.* (26) *Euplica scripta.* (27) *Euplica* sp. (28) *Anazola lutaria lutaria.* (29) *Olive athenia.* (30) *Volvarina* sp. (31) *Hastula bacillus.* (32) *Turritella terbra.* (33) *Faunus ater.* (34) *Faunus* sp. (35) *Epitonium aculeatum.* (36) *Tarebia* sp. (37) *Pagurus* sp. (38) *Terebralia sulcata.* (39) *Melanoides maculata.* (40) *Cerithium* sp. (41) *Cerithium breviculum.* (42) *Cerithium coralium.* (43) *Cerithium alveolum.* (44) *Cerithium kobelti.* (45) *Cerithidea cingulata.* (46) *Cerithidea weyersi.* (47) *Clypeomorus* sp. (48) *Clypeomorus petrosa.* (49) *Rhinoclavis sinensis.* (50) *Cellana radiate.* (51) *Conspisious chiton* (52) *Chicoreus torrefactus* (53) *Chicoreus siratus* (54) *Latirus craticulatus* (55) *Latirus* sp. (56) *Pleuroploca filamentosa* (57) *Gyrineum natator* (58) *Cymatium* sp. (59) *Cymatium muricinum* (60) *Cymatium rubeculum (61) Thais jubilaea (62) Thais kieneri (63) Thais rufotincta (64) Morula granulata (65) Morula marginalba (66) Semiricinula muricoides (67) Ergalatax margariticola (68) Orania dharmai (69) Engina alveolata (70) Drupella cornus (71) Cantharus undosus (72) Lambis chiragra*. *(73) Cypraea triserialis (74) Trochus stellatus (75) Trochus radiatus (76) Turbo bruneus (77) Euchelus asper quadrinatus (78) Euchelus* sp. *(79) Pseudostomatella papyracea (80) Natica catena (81) Trochus* sp. *(82) Clithon ovalaniensis (83) Clithon ovalaniensis (84) Clithon faba (85) Clithon corona (86) Clithon squarrosus (87) Natica* sp. *(88) Mitra litterata (89) Mitra paupercula (90) Mitra paupercula (91) Mitra scutulata (92) Mitra pica (93) Mitra ambigua (94) Mitra fulvescens (95) Nerita albicilla (96) Nerita plicata (97) Pyrene* sp. *(98) Pyrene fasciata (99) Pyrene fasciata (100) Pyrene testudinaria (101) Pardalinops testudinaria (102) Engina zonalis (103) Engina zonalis (104) Engina zonalis (105) Engina mendicaria (106) Anachis terpsichore (107) Vexillum* sp. **Bivalvia:** (1) *Donax* sp. *(2) Donax* sp. *(3) Donax* sp. *(4) Donax* sp. *(5) Chlamys* sp. *(6) Carditameira radiata (7) Anadara antiquata (8) Mytilus pictus (9) Ostrea odulis (10) Sunetta tuncata (11) Saccostrea cucullata (12) Tridacna gigas (13) Tridacna* sp. *(14) Barbatia* sp. *(15) Antigona reticulata (16) Perna viridis.* **Cepalopoda:** *(1) Loligo* sp. *(2) Octopus* sp. **Echinodermata:** *(1) Ophiothrix fragilis 1 (2) Ophiothrix fragilis 2 (3) Ophiocoma erinaceus (4) Ophiocoma sp. 1 (5) Ophiocoma* sp. *2 (6) Holothuria atra (7) Echinotrix calamaris (8) Echinometra oblonga (9) Diadema setosum (10) Colobocentrotus atratus.* **Nudibranchia:** *(1) Ceratosoma trilobatum (2) Ardeadoris* sp. *(3) Plakobranchus ocellatus.* **Cnidaria:** *(1) Spongia* sp. *(2) Heteractis aurora (3) Heteractis magnifica (4) Aiptasia* sp. *(5) Aiptasia pulchella (6) Aiptasia mutabilis (7) Haliclona* sp. *(8) Haliclona* sp. *(9) Actinia* sp. *(10) Anthopleura* sp. *(11) Aurelia aurita (12) Physalia physalis (13) Meandrina* sp. *(14) Diploria labyrinthiformis (15) Zoanthus sp.* **Arthopoda:** *(1) Scopimera globosa (2) Thalamita coeruleipes (3) Leptodius* sp. *(4) Eriphia sebana (5) Thalamita hellerii (6) Grapsus* sp. *(7) Charybdis riversandersoni (8) Uca* sp. *(9) Squilla mantis.* **Anelida:** *(1) Baseodiscus* sp. *(2) Baseodiscus hemprichii (3) Eunice* sp. *(4) Sabellastarte australiensis (5) Sabellastarte magnifica. (6) Sabbelasstarte spectabilis (7) Nereis* sp.

Distribution pattern

The distribution pattern of species richness for Gastropods and Anthozoans is concentrated in Karapyak, Pasir Putih, and Madasari, with a combined habitat of rock, coral, stone, sandy-mud, seagrass, and macroalgae (Fig. 3A). The density distribution of Gastropoda is at its highest in Muara Cijulang and Nusawiru, where the substrate is mud (Fig. 3B), while Anthozoa and Polychaeta are dominant in hard substrates at Karapyak, Pasir Putih, and Madasari. In contrast, Karang Nini, Batu Hiu, and Pantai Barat show the lowest species numbers and macroinvertebrate density (Fig. 3). Similarity analysis revealed that the distribution pattern of marine macroinvertebrates along the Pangandaran coast is grouped into four categories based on habitat (Fig. 4): group 1) Karapyak, Pasir Putih, and Madasari; group 2) Karang Nini and Batu Hiu; group 3) Muara Cijulang and Nusawiru; and group 4) Pantai Barat.

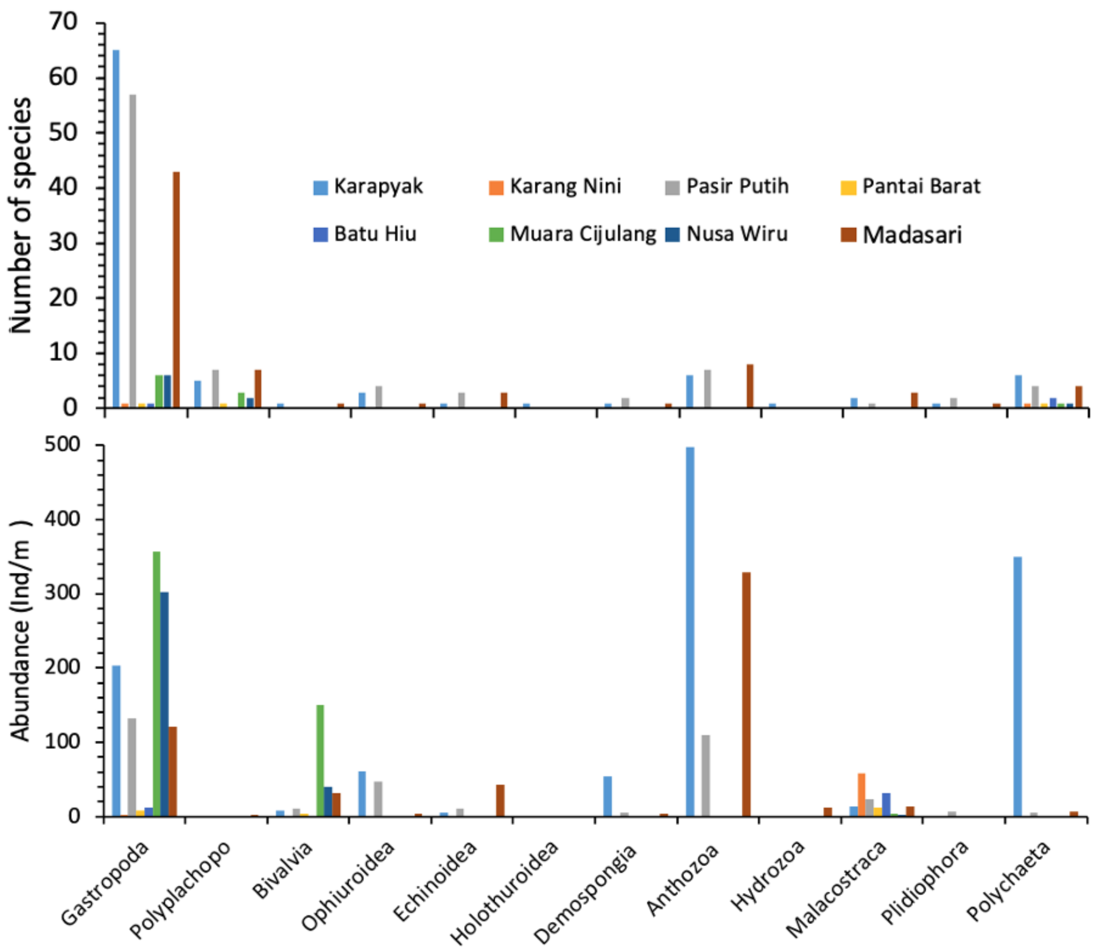

Fig. 5. Distribution of macroinvertebrates at Pangandaran coastal based on **A)** number of species and **B)** density

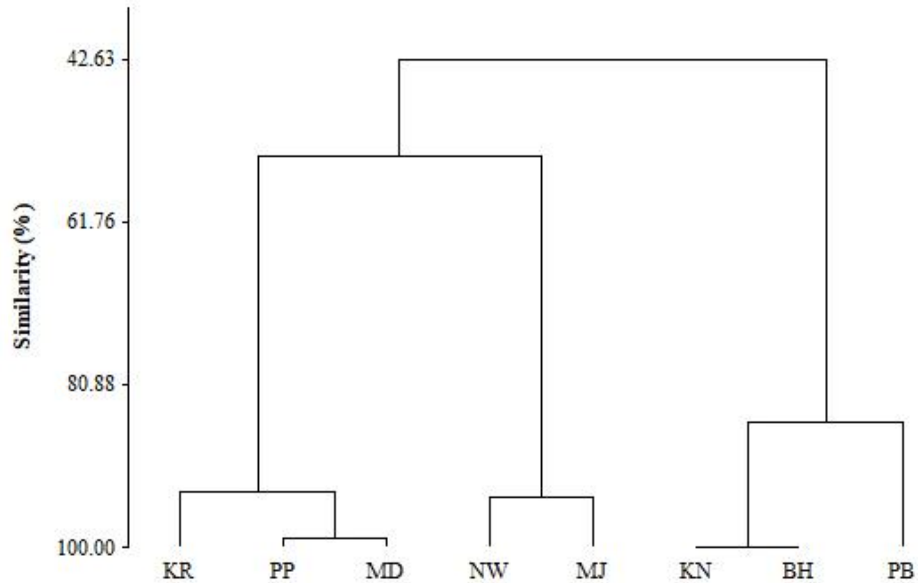

Fig. 6. Spatial distribution pattern of macroinvertebrates at Pangandaran coastal by similarity analysis based on sampling sites. Sampling sites: KR (Karapyak), KN (Karang Nini), PP (Pasir Putih), PB (Batu Hiu), MC (Muara Cijulang), NW (Nusawiru), and MD (Madasari)

DISCUSSION

Considering the importance of the Pangandaran coast for local biodiversity and the impact of tourism, monitoring this area is essential for the conservation of its biodiversity and habitat. We initiated this endeavor, executed a survey, and presented depictions of the biodiversity of marine macroinvertebrates in the region. Our study identified the biodiversity of marine macroinvertebrates, comprising a total of 160 species distributed throughout 13 classes and 7 taxa. The data illustrate the significant species richness of Pangandaran coast, highlighting the necessity to conserve their biodiversity. Moreover, we highlighted habitat types that are key to the spatial distribution of marine macroinvertebrates. A prior investigation by **Bissoli and Bernardino (2018)** and **Sahidin *et al.* (2019)** determined that substrate and ecological pressure influence macroinvertebrate diversity. The three substrate site sample locations are intertidal zones with a gradual slope, consisting of coral, rocky, sparse, and sandy substrates, and are inhabited by various kinds of algae and seagrass (Table 1). Prior research and additional investigations **(Amsler *et al.*, 2014; Rumahlatu & Leiwakabessy, 2017; Sahidin *et al.*, 2019)** confirm that gastropods are mollusks that aggregate and reside on hard substrates.

The collection of biota by tourists in these areas contributes to a decline in biodiversity. Tourists typically collect more mollusks than other varieties **(Zahedi, 2008; Kartika & Mu, 2014)** due to their large sizes and appealing shapes, rendering them more conspicuous to visitors. Habitat, anthropogenic influences, and water quality furthermore affect the spatial distribution and circumstances of invertebrates. Cluster analysis indicates that habitat characteristics, including coral-rocky, sandy, and muddy substrates, are key for cluster distribution. Nonetheless, a rise in tourism may adversely affect the environment and biodiversity of marine macroinvertebrate species in Pangandaran, although yielding economic advantages. The collection of attractive items by tourists, including fossils, invertebrate shells, and live invertebrates, leads to a decline in invertebrate populations **(Zehedi, 2008; Kartika & Mu, 2014)**. Pangandaran coast is a renowned location for the commerce of fossil decorations and invertebrate shells, especially those from the mollusk class **(Nijman *et al.*, 2016)**. Communities not only offer guidance but also commercialize fossils, shells, and living organisms for decorative, culinary, ornamental, and pharmaceutical purposes **(Nijman *et al.*, 2015; Nijman & Lee, 2016)**.

The Muara Cijulang and Nusawiru sites exhibit high abundance with poor species richness. We suggest that this occurs due to the dominance of a single species, specifically *Fanaus ater*. Both sites are positioned in an estuary characterized by a mud substrate and mangrove vegetation. A prior study indicated that *Faunus ater,* a macroinvertebrate inhabiting estuaries and associated with mangroves, functions as a bioindicator of organic pollution and accumulates heavy metals **(Agustina *et al.*, 2018; Indra *et al.*, 2019)**. The harsh environment of Karang Nini and Batu Hiu, marked by substantial, steep, rocky bottoms and vigorous waves, results in a low diversity and density of marine macroinvertebrates. The habitat type influences the diversity levels of macroinvertebrates in coastal regions **(Sahidin *et al.*, 2019)**.

Arthropods emerged as the third-largest phylum, following Mollusca and Cnidaria. The 10 species are active constituents of the Malacostraca class. *Clibanarius vittatus*, belonging to the Malacostraca class, predominates in all habitats; it is an active and dispersed crustacean found in rocky and sandy shorelines **(Christopher *et al.*, 2011; Vogt *et al.*, 2018)**. It possesses migratory capabilities **(Souza *et al.*, 2016; Rodrigues *et al.*, 2020)** and exhibits resistance to ambient temperatures and salinity **(Vogt *et al.*, 2018)**. The Karapyak rocky shore has four species of the phylum Cnidaria, which are solely located in rocky shore, including Karapyak, Pasir Putih, and Madasari Station. The species *Anthopleura elegantissima*, which predominates and is distributed in colonies, was found along the shoreline. *A. elegantissima* is a species of the class Anthozoa, highly sensitive to environmental factors, particularly salinity, currents, and depth **(Oualid *et al.*, 2016; Glon *et al.*, 2019)**. This trait results in the species' confinement exclusively to coastal regions subjected to continuous seawater exposure.

Annelida, particularly the Polychaeta class, represents a component of coastal ecosystems, thriving in rocky, muddy, and sandy shore environments **(Capa & Murray, 2016; Read & Fauchald, 2020)**. This study identified five Polychaeta species within the rocky shoreline of Pangandaran, particularly in Karapyak, Pasir Putih, and Madasari, with *Bispira brunnea* being the dominant species. The species *Bispira brunnea,* belonging to the class Polychaeta, is diminutive, reproduces sexually, and generates many planktonic larvae. This trait facilitates the dispersal of this species by currents, while the adult form adheres to corals influenced by tidal movements and colonies **(Hadianto, 2013; Muir & Hosain, 2014; Sahidin *et al.*, 2014; Naeini *et al.*, 2018; Keppel *et al.*, 2019)**. A previous study notably identified the foreign polychaete *Sabellastarte australiensis* in the Karapyak, originating from the New South Wales coast. The global map indicates that the Pangandaran shore directly adjoins the Indian Ocean, contiguous with the Australian continent. These species exhibit extensive distribution over the Asian and Australian continents.

CONCLUSION

A total of 160 marine invertebrate species from 13 classes and seven phyla have been identified along the Pangandaran coast, with mollusks making up the majority at 99 species, followed by Cnidarians with 8 species. The distribution pattern of marine invertebrates is categorized into four clusters: rocky ecosystem (Karapyak, Pasir Putih, and Madasari), muddy ecosystem (Nusawiru and Muara Cijulang), sandy ecosystem (Pantai Barat), and crag ecology (Karang Nini and Batu Hiu). The intertidal zone with rocky substrates exhibited higher diversity (3.99–5.08) compared to muddy, sandy, and crag substrates (0.65–2.16, 0.65, 0.50–0.80, respectively). The rocky substrate was dominated by *Cerithium breviculum*, *Thais jubilaea*, and *Anthopleura elegantissima*, while the muddy substrate was primarily inhabited by *Faunus ater*, *Terebia* sp., and *Clithon oualaniensis*. The sandy substrate exclusively hosted *Hastula bacillus* from the gastropods, and *Clibanarius vittatus*, a widely distributed crustacean species, was present across various substrates with a density of 69 ± 15 individuals per square meter. Spatial distribution studies highlighted that substrate type and anthropogenic activities are key factors influencing the distribution of macroinvertebrates along the Pangandaran coastline.

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