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Diversity and composition of Crustacean and Mollusk in mangrove area of Sampang and Pamekasan Districts, Madura Island, Indonesia

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Abstract. *Haqqi MRA, Sholichah DM, Ashila J, Reza AD, Indrawan M, Dadiono MS, Yap CK, Rahim KABA, Setyawan AD. 2024. Diversity and composition of Crustacean and Mollusk in mangrove area of Sampang and Pamekasan Districts, Madura Island, Indonesia. Indo Pac J Ocean Life 8: 59-71.* Mangrove ecosystem in Indonesia is the largest in the world and contains various biota with a great interest to study. An example of mangrove ecosystems can be found in Sampang and Pamekasan Districts, Madura Island which have a high potential for biodiversity, such as Crustacean and Mollusk. However, information regarding the diversity of Crustaceans and Mollusks in that territory is still very limited. Therefore, this research was conducted to assess the diversity of Crustaceans and Mollusks in the mangrove area of Sampang and Pamekasan Districts. The study was conducted in December 2023 with data collection located at four stations: (i) Taddan, Camplong Sub-district and (ii) Song-Osong Beach, Sampang Sub-district, both in Sampang District; (iii) Branta Tinggi and (iv) Raya Ambat Street both in Tlanakan Sub-district, Pamekasan District. Data on biotic and abiotic environmental parameters was collected and sampling of Crustacean and Mollusk was conducted using Visual Encounter Survey (VES) and direct catching. The results showed that mangrove ecosystem in Sampang and Pamekasan Districts had certain similarities, i.e. both were composed by vegetation of *Sonneratia alba*, *Avicennia marina*, *Sonneratia caseolaris*, and *Rhizophora mucronata*. The environmental parameters measurement showed that the study area location has warm temperatures, wet soil, neutral pH, and relatively low salinity compared to Madura Strait. There were 32 Crustacean species with the mostly found was *Balanus* sp. (barnacle), followed by *Clibanarius longitarsus* (common hermit crab). The number of Mollusks obtained was 24 species with the mostly found was *Pirenella alata* and *Pirenella cingulata*. Based on ecological indices calculation, Crustacean on study area location had moderate diversity, high species richness, high evenness or stable community, and indicates no dominant species. While the Mollusk on study area location had moderate diversity, moderate species richness, high evenness or stable community, and indicates no dominant species. Station 3 (Branta Tinggi) had the highest number of Crustacean species, diversity, species richness, and evenness, while Station 4 (Raya Ambat Street) had the highest number of Mollusk species, diversity, species richness, and evenness.

Keywords: Crustacean, diversity, environment, Mollusk, mangrove

INTRODUCTION

Indonesia is an archipelagic country located at the equator and is among mega biodiversity countries along with Brazil, Colombia, and Zaire due to its high diversity of flora and fauna (Supriatna 2008). As a country composed of chain of islands, Indonesia has one of the longest coastlines in the world, stretches for 95,181 km (Subagio 2013), which consist of various complex ecosystems of marine and terrestrial realms. One of the unique coastal ecosystem found In Indonesia is mangrove, extending over 5,000 km from east to west (Supriatna 2008). Mangrove forest in Indonesia contributes to 50% of the total area of mangrove forests in Asia and almost 30% of the world (Onrizal 2018), making it as the country with the largest extent of mangrove in the world. Mangrove forests can be found in the entire region of Indonesia, both in areas with wet and dry seasonal climates, with the largest area is in Papua (Kartawinata 2013).

Mangrove ecosystem is located on transitional zone between terrestrial and marine realms, and is flooded by sea water during high tide and exposed to the air during low tide. It is characterized by salt-tolerant vegetation with complex root systems (Soeprobowati et al. 2024). Mangrove tree live in the intertidal zone of coastal bays and can may grow toward land for hundreds of meters where the area is far from the influence of ocean tides (Swasta 2018). Mangrove ecosystem is composed by interacting biotic and abiotic components between marine and terrestrial ecosystems which form unique features including the presence of mangrove vegetation (Saptutyningsih 2023). Mangrove forests grow and develop

in estuary area, making it become biodiversity hotspots that providing habitat as a nursery, spawning and feeding grounds for various aquatic and terrestrial biota such as birds, fishes, shrimps, and crabs (Rangkuti et al. 2017).

Mangrove ecosystem are good examples of complex habitats, since they are among the most diverse and productive habitat types in coastal areas. On mangrove ecosystem, marine benthic invertebrates become keystone organisms which play an important role to create mangrove ecosystem complexity due to their horizontal and vertical distributions (Hajializadeh et al. 2020). The presence and activity of those macrozoobenthic animal has an effect that can influence the interaction and life of other components in mangrove ecosystem. The ecological importance of this animal in mangrove ecosystem includes as decomposer organism, promoting carbon and nutrient recycle, source of mineral for nature, improve oxygen aeration, and provide natural food for another biota (Ginantra et al. 2023). Crustaceans have an important position within the aquatic ecosystems at various food web levels, including as predators, scavengers, or filter feeders (Knigge et al. 2021). Mollusks play a role as a food chain detritus feeder in the nutrient cycle because Mollusks are early decomposers that chop mangrove leaves into small parts before consumed by smaller organisms (Odum 1996; Baderan et al. 2019). Some species of Crustaceans and Mollusks are used as water quality bioindicators and have economic value for human consumption (Sianipar et al. 2022). A better understanding of mangrove invertebrate ecology, especially Crustaceans and Mollusks, will help promote mangrove ecosystem conservation (Setyadi et al. 2021).

Mangrove ecosystem also occurs in Sampang and Pamekasan Districts, Madura Island, Indonesia, where the mangrove forests are mostly located at the sea edges with silt and sand substrates (Suprakto 2005; Muhsoni et al. 2013). Mangroves in Sampang and Pamekasan Districts are located in the south coast of Madura Island and have a vital role for local communities. Local people usually harvest shrimp, snail, clam, crab, and several types of fish from those location for economic and livelihood household needs (Arkham et al. 2018; Islamy and Hasan 2020). Several research related to the diversity of Crustacea and Mollusk in Sampang District have been done by Adhani et al. (2018), Pratiwi and Muhsoni (2021), and Wijaya and Ambarwati (2021), while similar research in Pamekasan District were carried out by Rahmasari et al. (2015), Farid et al. (2023), Istifadah and Ibana (2023), Iwandani et al. (2023), Afnani and Rahayu (2024) and Kurniawan et al. (2024). However, those research were limited to studying several classes or genera with incomplete biodiversity data because the focus of their study is not on diversity. Therefore, this study was conducted to fill the research gap related to ecological data, including abundance, diversity, distribution, dominance, evenness, species richness, and morphological record from Crustacean and Mollusk that found in mangrove area of Sampang and Pamekasan Districts. The results of this study are expected to serve as baseline data for future monitoring and to be used as consideration in restoration, conservation, and development strategies of mangrove areas in Sampang and Pamekasan Districts.

MATERIALS AND METHODS

Study period and area

The study was conducted in December 2023 and located in the mangrove ecosystem in the districts of Sampang and Pamekasan, Madura Island, East Java Province, Indonesia. Data collection was conducted at four stations i.e.: (i) first station located in Taddan, Camplong Sub-district, Sampang District; (ii) second station located in Song-Osong Beach, Sampang Sub-district, Sampang District; (iii) third station located in Branta Tinggi, Tlanakan Sub-district, Pamekasan District; and (iv) fourth station located aside of Raya Ambat Street, Tlanakan Sub-district, Pamekasan District (Figure 1). These four locations were determined to represent mangrove areas with different kinds and characteristics of the two districts. Taddan and Song-Osong Beach, respectively represented dense and sparse mangrove vegetation in Sampang, while Branta Tinggi and Raya Ambat Street, respectively represented dense and sparse mangrove vegetation in Pamekasan.

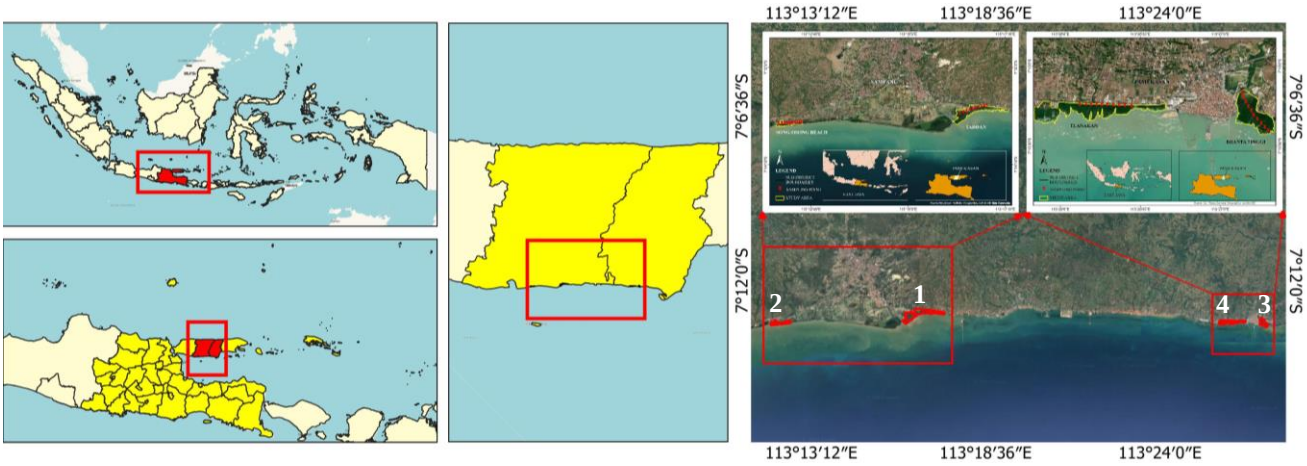

Figure 1. Map of study area showing four stations in Madura Island, East Java, Indonesia: Station 1 Taddan and Station 2 Song-Osong Beach in Sampang District; and Station 3 Branta Tinggi and Station 4 Raya Ambat Street in Pamekasan District

Data collection procedures

Environmental parameters

Environmental parameters were measured at each station to determine its conditions. According to Hariyanto et al. (2018), abiotic environmental factors influence animal groups' presence and population density, so the measurement can help determine the structure of animal communities in their habitat. Measured abiotic parameters were air temperature, soil temperature, water temperature, water pH, soil pH, water salinity, and soil moisture. The measurement was repeated thrice to improve the accuracy. The equipment used to measure the abiotic parameters were soil test kits for measuring soil temperature, soil pH, and soil moisture; thermometers for measuring air and water temperatures; and refractometers for measuring water salinity. Biotic environmental factors being investigated were the types and the most dominant mangrove species in the study area.

Crustacean and Mollusk sampling

Examination of Crustacean and Mollusk species in study area location was conducted by active sampling method, which was performed by Visual Encounter Survey (VES) and direct catching with scoop nets (Riper et al. 2010; Ng 2017). VES is preferred in time-constrained studies for observing species richness and abundance along a survey path (Heyer et al. 1994). VES was carried out by walking along the whole perimeter or accessible survey path and observing the signs or presence of target species (Tiberti et al. 2022); the samples acquired were caught and documented using a digital camera. In this study, the VES method was also used to maximize the results obtained due to limited access to samples due to the abundance of mangrove trees.

Measurement of distribution was conducted on 50 × 50 meter bot to the right and left of coastline along survey path. The distribution and abundance data collection method were refers to Ginantra et al. (2023), where species distribution was determined based on the presence and number of individuals of each species on each study area location. While the abundance of each species was calculated based on the number of individuals per unit area (m^2). The scientific names, numbers, and locations of observed samples were recorded. Identification of species was carried out using several guides, such as Marine Decapod Crustacea of Southern Australia: A Guide to Identification (Poore 2004); E-Booklet *Keanekaragaman Jenis Udang di Kawasan Sungai Bagandis, Kabupaten Tanah Laut* (Kaspul and Halang 2022); *Pedoman Identifikasi Udang* (Subordo Macrura Natantia) (Saputra 2008); Catalogue of the Marine Shells of Australia and Tasmania, Volume 1: Cephalopoda. Pteropoda. Gasteropoda (John 1892); E-Book *Keanekaragaman Moluska: Bivalvia, Gastropoda, Polyplacophora* (Steviana 2020); *Moluska: Karakteristik, Potensi, dan Pemanfaatan Sebagai Bahan Baku Industri Pangan dan Non Pangan* (Nurjanah et al. 2021). Identification is also done with the help of a global biodiversity database and software such as Global Biodiversity Information Facility (GBIF) and iNaturalist.

Data analysis

Analysis was performed qualitatively and quantitatively. Qualitative analysis was carried out by descriptive analysis, which provides an overview or description of a situation or condition without any treatment of the object being studied (Rompas 2014). Descriptive analysis was carried out through literature review, while the morphological record was depicted through documented Crustacea and Mollusk samples. Meanwhile, quantitative analysis was conducted by calculating several ecological indices; Shannon-Wiener diversity indices $[H' = \sum_{i=1}^{s} pi \ln pi]$, Margalef species richness indices $\left[R_1 = \frac{(S-1)}{Ln(N)}\right]$, Pielou evenness indices $\left[E_1' = \frac{H'}{H_{max}}\right]$, and Simpson dominance indices $\left[C = \Sigma \left[\frac{n_i}{N}\right]^2\right]$ (Hidayat and Nurulludin 2017). Results from calculation then analyzed regarding measured environmental parameters and station characteristics so that the correlation between ecological aspects of Crustaceans and Mollusks with the environmental factors in the study area can be acquired.

RESULTS AND DISCUSSION

Environment characteristics of sampling location

The environmental characteristics were examined from biotic and abiotic factors as benchmark parameters. The biotic parameter was the diversity of mangrove species at each station. The observation showed that the mangrove area at each station has certain similarities, including species, vegetation appearances, and substrate characteristics such in Table 1. Mangrove species found at the first station (Taddan) were *Avicennia marina* and *Sonneratia alba*, while mangrove species found at the second station (Song-Osong Beach) were *A. marina*, *Sonneratia caseolaris*, and *Rhizophora mucronata*. Mangroves at Taddan was mainly distributed as a group because mangroves reproduce by falling their seeds close to their progenitor (Muhsoni 2020). According to Zainuri et al. (2014), mangroves in Sampang Sub-district has a density of >1,500 trees/ha on 50.88% of its area, meaning that most of the mangroves has very dense vegetation. In Branta Tinggi, Pamekasan District, only one mangrove species was found, namely *R. mucronata*. Meanwhile, at Raya Ambat Street, Pamekasan District, two species of mangroves were found: *A. marina* and *R. mucronata*. The lower diversity of mangrove species in Pamekasan District compared to Sampang District can be caused by degradation since the mangrove forest areas were converted into residential, salt industrial areas, aquaculture, as well as the death of mangrove vegetation due to sand mining and plastic waste disposal (Sukandar et al. 2016).

The four stations were coastal areas located in the southern part of Madura Island and were directly adjacent to the Madura Strait. Each station area shaded by mangrove vegetation and open area. Stations 1 and 3 had mangrove vegetation substrates that tend to be muddy sand, while Stations 2 and 4 had mangrove vegetation substrates that

tend to be sandy. Based on environmental parameters measurement, all stations had warm temperatures, tended to be neutral in pH, and possessed wet soil characteristics. The salinity level of the Madura Strait Waters ranged between 31.8 to 32.77 ppt (Abdulrohiim et al. 2022), so it can be said that the average water salinity at the study location tended to be low compared to Madura Strait. Sea depth can influence salinity, where the increase in salinity is directly relative to the sea depth level. The influx of fresh water in those areas also influences salinity (Suhana 2018). The lowest salinity level occurs in Station 2 due to ponds and brackish water flows. Based on the observations, local residents carried out various activities at all stations, such as parking boats, fishing, and gathering animals, such as crabs and clams, for consumption.

Crustacean diversity, abundance, and morphological record

From the data collection that has been done, it is known that there are two groups of taxa from the subphylum of Crustacea in the study area location, which are Decapoda and Cirripedia. The results showed that there were a total of 32 species of Crustacea consisting 13 families of Decapoda and 1 family from Cirripedia. Decapoda belongs to group of Malacostraca, which has modified first three pairs of thoracic limbs called maxillipeds as feeding organs appendages. While the last five pairs of thoracic limbs are involved in locomotion (Poore and Ahyong 2023). The decapod groups consist of prominent marine animals, such as shrimps, prawns, crabs, and lobsters. Meanwhile, Cirripedia belongs to the group Thoracica, which is characterized with confounded cephalic and thoracic segments. Cirripeds are permanently attached, even before their final metamorphosis, by tissue or cement (Darwin 1854). At the lower level of taxa, Crustacean at the study area location was composed of Anomura or hermit crabs (12.50%), Brachyura or true crabs (68.75%), Caridea or true shrimps (15.63%), and Cirripedia or barnacles (3.13%). The diversity and abundance of Crustacean species found in the study area is presented Table 2.

The majority of the Crustacean species discovered are typically found in intertidal habitats, such as beaches, estuaries, coral reefs, and mangroves. The most commonly found Crustacean species in study area location was *Balanus* sp. (barnacle), followed by *Clibanarius longitarsus* (common hermit crab). This explains why both of those species have the highest density on study area location. *Balanus* sp. or commonly known as barnacle is a species from class of Hexanauplia, infraclass of Cirripedia, order of Balanomorpha, and family of Balanidae. The members of the Balanidae are characterized by diametric growth and may have four or six wall plates. Balanids basal plate are calcareous, which attaches the animal directly to the substrate (Darwin 1854; Newman and Arnold 1976; Checa et al. 2019). Growth in height is achieved by growth of the plate parietes at their dorsal (basal) margin, while growth in width of the aperture takes place both at the cardinal growth surface of the radii and at the rostral growth margins of the alae. Radii grow towards the carina, whereas alae grow towards the rostrum (Checa et al. 2019). While *C. longitarsus* is belongs to family of Diogenidae, which characterized by poor calcification of the cephalothorax and uncalcified, asymmetric abdomen, and distinguished by the third pair of its maxillipeds are close together and the chelipeds are either equal or the left is larger than the right (Hazlett 1966). In all four stations, as many as 6 species have an even distribution, namely *Balanus* sp., *C. longitarsus*, *Uca dussumieri*, *Uca annulipes*, *Uca vocans*, and *Thalamita crenata*. In this study, Brachyura had the most diversity among other Crustaceans with 22 species from 8 families, followed by Caridea with 5 species from 3 families, Anomura with 4 species from 2 families, and Thoracica with a single species from 1 family. .

Brachyura is a group of Crustacean that often referred to as ‘true crabs’ that characterized by exoskeletons that are moulted for the animal to grow (even during larval stages), segmented bodies, stalked eyes, carapaces broader than they are long, similar appendages and mandibles. Most crabs, the first pair of legs (the chelipeds) is used for feeding and the legs terminate in curved, two-part claws or pincers (the chela) (Chris 2021). Caridea consist of shrimp-like decapods that belongs to the class of Malacostracea, which has a head consisting of a preantennular region bearing the eyes, followed by five segments with appendages (two pairs of antennae, three pairs of mouthparts), a thorax of eight segments, and an abdomen with usually six (sometimes seven) segments, most of which bear appendages. Another distinctive feature defining this group is the position of gonopores (female apertures on the sixth, male apertures on the eighth thoracic segment) (Bauer 2004). Anomura is an infraorder of decapod Crustaceans that are nearest relatives of the Brachyura and unifying group of hermit crabs (Paguroidea), squat lobsters, porcelain crabs (Galatheoidea), and mole crabs (Hippoidea). It main characters is very small size, reduced last walking legs, and has an uncalcified groove along the sides of the carapace (the *linea anomurica*). The last pair of walking legs is so reduced that most anomurans appear to have only six instead of eight walking legs at first sight (Hutchings et al. 2009) and Thoracica were characterized by confounded cephalic and thoracic segments, which has sessile parts that externally visible and divided into the operculum or opercular valves (*valvae operculares*) and the shell (*testa*) (Darwin 1854). Morphological record of Crustacean that found in study area location can be seen in Figure 2.

Based on the calculation results, the mangrove area in Sampang and Pamekasan Districts, Madura Island, Indonesia, has Crustacean diversity indices of 2.60 which means moderate, species richness indices of 4.05 which means high, evenness indices of 0.75 which indicates high evenness or stable community, and dominance indices of 0.10 which indicates no dominant species. The diversity, evenness, and dominance indices for each station does not show any significant difference, when compared to each other station. Meanwhile there were differences in the results of species richness between observation stations, where Stations 2 and 4 shows low, while Stations 1 and 3 shows moderate levels of species richness. Apart from that, Station 3 (Branta Tinggi) has the highest number of

Crustacean species, diversity, species richness, and evenness among other station in this study. The results of calculation can be seen in Table 3.

Table 1. Environment characteristics measured at the sampling station of mangrove ecosystem in Sampang and Pamekasan Districts, East Java, Indonesia

Parameter	Station			
	1	2	3	4
Mangrove species	*A. marina*, *S. alba*	*A. marina*, *S. caseolaris*, *R. mucronata*	*R. mucronata*	*A. marina*, *R. mucronata*
Water temperature (°C)	±30.67	±35.67	±34.33	±36
Soil temperature (°C)	±30.33	±34.67	±34.33	±35
Air temperature (°C)	±31.7	±36.33	±37.17	±36.33
Water pH	±7.6	±7.53	±7.37	±8.03
Soil pH	±6	±6.97	±6.8	±7.1
Water salinity (ppt)	±28.33	±19.67	±28.33	±32.67
Soil moisture	>10	>10	>10	>10
Substrate characteristics	muddy sand	sandy	muddy sand and soil	muddy sand with a bit of coral rock

Table 2. Diversity and abundance of Crustacean species at the sampling station of mangrove ecosystem in Sampang and Pamekasan Districts, East Java, Indonesia

Family	Species	Attendance in station				Density (Ind/5m^2)
		1	2	3	4	
Cirripedia: Thoracica						
Balanidae	*Balanus* sp.	●	●	●	●	80.8
Decapoda:Anomura						
Diogenidae	*Clibanarius cruentatus* (H.Milne-Edwards, 1848)	●	●	●	●	20
	Clibanarius longitarsus (De Haan, 1849)	●	●	●	●	56.2
Porcellanidae	*Petrolisthes armatus* (Gibbes, 1850)	●	-	●	-	2.2
	Petrolisthes asiaticus (Leach, 1820)	●	-	-	-	1
Decapoda: Brachyura						
Dotillidae	*Scopimera globosa* (De Haan, 1835)	-	●	-	-	12.4
	Ilyoplax orientalis (De Man, 1888)	-	-	●	-	10.2
Grapsidae	*Metopograpsus* sp.	-	-	-	●	0.4
	Metopograpsus frontalis (Miers, 1880)	-	●	●	●	6.6
	Pachygrapsus crassipes (Randall, 1840)	●	-	-	-	2.4
	Pachygrapsus marmoratus (Fabricius, 1787)	-	-	●	-	0.6
	Pachygrapsus plicatus (H.Milne Edwards, 1837)	●	-	●	●	2
	Planes minutus (Linnaeus, 1758)	-	●	-	-	1.8
Macrophthalmidae	*Macrophthalmus crassipes* (H.Milne Edwards, 1852)	●	-	-	-	0.2
Mictyridae	*Mictyris longicarpus* (Latreille, 1806)	-	●	-	-	0.8
Ocypodidae	*Uca annulipes* (H.Milne Edwards, 1837)	●	●	●	●	43.8
	Uca dussumieri (H.Milne Edwards, 1852)	●	●	●	●	47.2
	Uca lactea (De Haan, 1835)	●	●	-	●	28
	Uca perplexa (H.Milne Edwards, 1852)	-	-	●	-	5.2
	Uca vocans (Linnaeus, 1758)	●	●	●	●	48.2
	Ocypode cordimana (Latreille, 1818)	-	●	-	-	1.2
Portunidae	*Charybdis helleri* (A.Milne-Edwards, 1867)	-	-	●	●	2.2
	Thalamita crenata (Rüppell, 1830)	●	●	●	●	15.4
	Thalamita prymna (Herbst, 1803)	-	-	●	-	1.8
Sesarmidae	*Episesarma versicolor* (Tweedie, 1940)	●	-	●	-	11.4
	Parasesarma pictum (De Haan, 1835)	●	-	●	-	4.2
Xanthidae	*Leptodius exaratus* (H.Milne Edwards, 1834)	●	-	-	●	1.6
Decapoda: Caridea						
Alpheidae	*Alpheus digitalis* (de Haan, 1844)	-	●	●	-	3.4
	Alpheus sp.	●	-	●	-	0.6
	Arete indicus (Coutière, 1903)	-	-	-	●	3.6
Atyidae	*Caridina* sp.	-	●	-	-	0.6
Palaemonidae	*Macrobrachium* sp.	-	●	-	-	3

Decapoda: Anomura


Clibanarius cruentatus


Clibanarius longitarsus


Petrolisthes armatus


Petrolisthes asiaticus

Decapoda: Brachyura


Charybdis hellerii


Episesarma versicolor


Ilyoplax orientalis


Leptodius exaratus


Macrophthalmus crassipes


Metopograpsus frontalis


Metopograpsus sp.


Mictyris longicarpus


Ocypode cordimana


Pachygrapsus crassipes


Pachygrapsus marmoratus


Pachygrapsus plicatus


Parasesarma pictum


Planes minutus


Scopimera globosa


Thalamita crenata


Thalamita prymna


Uca dussumieri


Uca lactea


Uca annulipes


Uca perplexa


Uca vocans

Decapoda: Caridea

Alpheus digitalis *Alpheus* sp. *Arete indicus* *Macrobrachium* sp. *Caridina* sp.

Cirripedia: Thoracica

Balanus sp.

Figure 2. Crustacean species in mangrove ecosystem in Sampang and Pamekasan Districts, East Java, Indonesia

Mollusk diversity, abundance, and morphological record

The study documented 24 Mollusk species from 17 families in the study area location, which composed of 3 classes, namely Gastropoda (58.33%), Bivalvia (37.5%), and Polyplacophora (4.17%). Gastropoda has the highest number of species among other families that consists of 14 species, and at the same time having the highest average population density. The most abundant species which also occurred all stations were *Pirenella alata* and *Pirenella cingulata*. Both are the same genera commonly found in several shores in the Pacific Ocean, Indian Ocean, to the Mediterranean Sea. This species is also often found in mangrove areas and mudflat substrates associated with outer to mid-range estuaries (Reid and Ozawa 2016: Wintah 2018). *Pirenella* sp. is usually found in a very dense distribution, resulting in high abundance. The observations also revealed that most of the Mollusks lived in a colony. Several Mollusk species, such as *P. alata, P. cingulata, P. maculata,* and *N. nigrita*, were seen attached to substrates such as sediment, coral rocks, and mangrove roots. While some others were only found by their shells, which may exist because sea currents swept them away. The diversity and abundance of Mollusk species found in the study area is presented Table 4.

Mollusk is a phylum of animal that are hugely successful to spread through marine environment and inhabit various ecosystems such as seabed, open waters, ocean surfaces, to shores (Gilpin 2006). From the several Mollusk families that found, Gastropoda being the most diverse on study area location, followed by Bivalvia and Polyplacophora. Gastropoda is the largest class of Mollusk and exhibit enormous diversity in form of shape and habitat. Limpets, top shells, abalone shells, periwinkles, slipper shells, and whelks are well known to observe. They are possess a muscular foot for creeping or burrowing, a head with sensory tentacles and eyes, a characteristic rasping radula (absent in some), and the mantle secretes the shell to provide a shelter (Carlton 2007). Typical character of gastropods are the head and foot arise from the same region, so they called head-foot or cephalopodium, which making it very difficult to differentiate where the head ends or the foot begins (Ray 2017). A lot of marine gastropods are benthic and mainly epifaunal that lived in the deep sea to the water surface (Santhanam 2019). The majority of gastropods that found in this study were species that commonly live in littoral zone, and species from Potamididae family was the most diverse and dominant among others Mollusk, including *Pirenella* sp. which is typically can only be found on mangrove ecosystems (Egonmwan 2008; Arbi et al. 2019).

Other Mollusk classes that found were Bivalvia and Polyplacophora. Bivalvia is the second largest class within the Mollusk, which characterized by two mantle lobes cover the body organs and secrete the two shell valves that are hinged dorsally (Gosling 2015). Bivalve are thought to have originated in warm shallow euhaline coastal waters and gradually invaded estuaries and brackish systems, as well as the reaches of the world ocean. Because adults forms of the majority of these animals are benthic or bottom dwelling, many different evolutionary adaptations to the benthic habitat have occurred (Dame 2012). Meanwhile Polyplacophora or chitons include about 600 extant species that entirely marine. They inhabit hard bottoms and rocky coasts in all of the world's ocean. Although commonly intertidal, living chitons have been dredged from waters as deep as 7000 meters (McKenzie and Parker 2019). Most chitons are grazers, feeding by scraping matter from the substrates using a complex radula with some teeth that have cutting edges reinforced with magnetite (Scheltema et al. 2001). Morphological record of Mollusk that found in study area location can be seen in Figure 3.

According to the calculation results, the mangrove area in Sampang and Pamekasan District, Madura Island, Indonesia, has Mollusk diversity indices of 2.61 which means moderate, species richness indices of 3.02 which

means moderate, evenness indices of 0.82 which indicates high evenness or stable community, and dominance indices of 0.11 which indicates no dominant species. The data from calculation also shows that each station has moderate diversity, low species richness, high evenness or stable community, and no dominant species. Apart from that, Station 4 (Raya Ambat Street) has the highest number of Mollusk species, diversity, species richness, and evenness among other station in this study. The results of calculation can be seen in Table 5.

Table 3. Diversity, species richness, evenness, and dominance indices calculation of Crustacean from mangrove ecosystem in Sampang and Pamekasan Districts, East Java, Indonesia

Calculation	Station				Entire study area location
	1	2	3	4	
Number of species found	17	16	18	14	32
Diversity indices	2.25	2.29	2.49	2.13	2.60
Species richness indices	2.57	2.44	2.66	2.07	4.05
Evenness indices	0.79	0.83	0.86	0.81	0.75
Dominance indinces	0.14	0.14	0.10	0.14	0.10

Table 4. Diversity of Mollusk species at the sampling station of mangrove ecosystem in Sampang and Pamekasan Districts, East Java, Indonesia

Family	Species	Location found				Density (Ind/5m^2)
		1	2	3	4	
Bivalvia						
Cardiidae	*Fulvia tenuicostata* (Lamarck, 1819)	●	-	-	●	4.2
Isognomonidae	*Isognomon alatus* (Gmelin, 1791)	-	-	-	●	10.2
Mytilidae	*Perna* sp.	●	-	-	-	1.4
Pinnidae	*Atrina fragilis* (Pennant, 1777)	-	●	-	-	2.4
Solenidae	*Solen* sp.	-	●	-	-	7.2
Veneridae	*Gafrarium pectinatum* (Linnaeus, 1758)	●	-	●	-	6.8
	Marcia hiantina (Lamarck, 1818)	●	●	-	●	28
	Marcia japonica (Gmelin, 1791)	-	●	-	-	2.4
	Placamen chloroticum (R.A.Philippi, 1849)	-	-	-	●	3.4
Gastropoda						
Ampullariidae	*Pomacea maculata* (Perry, 1810)	-	-	-	●	7.8
Assimineidae	*Assiminea brevicula* (L.Pfeiffer, 1855)	-	-	-	●	20.4
Buccinidae	*Buccinum sp.*	-	-	-	●	12.4
Cerithiidae	*Cerithium carnaticum* (Melvill & Standen, 1898)	●	-	-	●	25.2
Littorinidae	*Littoraria angulifera* (Lamarck, 1822)	-	●	-	●	20
Naticidae	*Natica gualteriana* (Récluz, 1844)	-	-	-	●	6.4
Neritidae	*Nerita nigrita* (Röding, 1798)	●	-	-	●	14.8
	Nerita lineata (Gmelin, 1791)	-	-	●	●	18.6
Olividae	*Oliva irisans* (Lamarck, 1811)	-	●	●	●	12.2
Potamididae	*Pirenella alata* (R.A.Philippi, 1849)	●	●	●	●	94.8
	Pirenella cingulata (Gmelin, 1791)	●	●	●	●	72
	Telescopium telescopium (Linnaeus, 1758)	-	●	●	-	4,2
	Terebralia sulcata (Born, 1778)	-	●	-	-	10.4
Trochidae	*Umbonium vestiarium* (Linnaeus, 1758)	-	●	●	●	18.2
Polyplacophora						
Chitonidae	*Chiton* sp.	-	●	-	-	0.4

Table 5. Diversity, species richness, evenness, and dominance indices calculation of Mollusk from mangrove ecosystem in Sampang and Pamekasan Districts, East Java, Indonesia

Calculation	Station				Entire Study Area Location
	1	2	3	4	
Number of species found	8	12	7	16	24
Diversity indices	1.74	2.23	1.63	2.57	2.61
Species richness indices	1.16	1.86	1.01	2.22	3.02
Evenness indices	0.84	0.90	0.84	0.93	0.82
Dominance indinces	0.21	0.13	0.23	0.09	0.11

Bivalvia

Atrina fragilis *Fulvia tenuicostata* *Gafrarium pectinatum* *Isognomon alatus*

Marcia hiantina *Marcia japonica* *Perna* sp. *Solen* sp. *Placamen chloroticum*

Gastropoda

Assiminea brevicula *Buccinum* sp. *Cerithium carnaticum* *Natica gualteriana*

Littoraria angulifera *Nerita nigrita* *Nerita lineata* *Oliva irisans* *Pirenella alata*

Pirenella cingulata *Pomacea maculata* *Telescopium telescopium* *Terebralia sulcata* *Umbonium vestiarium*

Polyplacophora

Chiton sp.

Figure 3. Mollusk species in mangrove ecosystem in Sampang and Pamekasan Districts, East Java, Indonesia

Discussion

In this study, the four stations were mangrove forest areas that had different vegetation, environmental characteristics, and species composition of Crustaceans and Mollusks. Based on the data obtained, 32 species of Crustacea and 24 species of Mollusks were found. The abundance of two Crustacean species that being the most found on study area location: *Balanus* sp. and *Clibanarius* sp., can be occurred mainly due to its intrinsic characters; reproductive behavior, growth rate, adaptability, and habitat suitability (Noda 2004; Rudi and Fadli 2009, Fitriani et al. 2024). Apart from that, biological behavior factors of each species also greatly influence its density. *Balanus* sp. or barnacles are a highly successful group in global dispersion and are usually found in aggregations of conspecifics and other fouling organisms (Newman and Arnold 1976; Torres et al. 2012). Barnacles can be transported as fouling on the hull of ships or as larvae in ballast water. Its larvae can survive for a long time and settle on hulls of ships staying in harbours and then can grow very quickly while carried away to other areas. Many barnacles are benefited from this condition to reach new regions where they often successfully colonized harbor installations, pontoons, and floating objects, such as buoys and other hard substrata (Torres et al. 2012). Barnacles can also secrets arthropodine compounds that able to attract other barnacles to gather and form a colony (Boesono 2010; Rizki et al. 2013). *Clibanarius* sp. or common hermit crab is a Crustacean that generally found in the Indo-West-Pacific tropical mangrove forests and recorded in several countries (Richmond 1997; Hossain et al. 2015). Common hermit crab inhabits benthic, littoral, rivers, creek mouths, and mangrove habitats, typically mud to muddy-sand substrates (Davie 2002). Those habitat characteristics were very suitable with the description of the study area location, which has the same substrate characteristics and is supported by certain environmental factors, making it an ideal habitat for the common hermit crab. In addition, a study by Varadarajan and Subramoniam (1982) shows that stable environmental temperature throughout the year, moderate changes in salinity, and plenty of nutrient availability may well be conducive support for continuous reproduction for species of hermit crabs.

The highest number and density of Mollusk that found on study area location was *P. alata* and *P. cingualata* that belongs to the Potamididae family, which typically can only be found in mangrove ecosystems (Egonmwan 2008; Arbi et al. 2019). They inhabit the mudflats of the mangrove swamps and quiet waters where the substratum is muddy and rich in detritus. They also have a habit of migrating to the edges of the water and congregating under tufts of grasses and breathing root of the mangrove plants, which shading them from direct sun light. The preference for muddy deposits may be correlated with the species being deposit feeders, taking in the mud, and digesting the detritus and other organic matter (Egonmwan 2008). Mangrove habitat provides shelter to this species, thereby supporting its growth population and, hence, abundance. Moreover, *Pirenella sp.* can starve for up to 28 days, adding to its ecological tolerance and population survivorship (Bhatt et al. 2020). *Pirenella* sp. is considered to be an indicator for and can be used as source of information on the bioavailability of contaminants in the ecosystem. In addition, this genus can also show changes in the physical environment of the mangrove ecosystem that can provide real effects on organism abundance and biodiversity (Auliatuzahra et al. 2022).

The population density of Crustacean ranges from 0.6-80.8 ind/5m^2, while for Mollusk ranges from 0.4-94.8 ind/5m^2. The range of Mollusk population density is higher because on study area location Mollusks are more often found in groups in larger numbers. In addition, they are also found on more varied substrate types such as coral rocks, tree roots, sand, mud, trunks, to ship's hull. Based on indices calculation, Crustacean and Mollusk in study area location indicates moderate diversity, high evenness or stable community, and no dominant species. But species richness of Crustacean indicates high, while species richness of Mollusk indicates moderate. The mangrove environment in both locations has an ecosystem condition that is suitable and able to support life and diversity of Crustaceans and Mollusk, both for species that have associations with mangrove habitats or species that live in intertidal habitats. The lower species richness of Mollusk than Crustaceans can be caused by human activities, due to the community around the four stations who often look for small fish and macrozoobenthos as food when the sea begins to recede. Mollusk has slower movements compared to Crustacean, which makes them easier to catch. Station with the highest number of Crustacea species, diversity, species richness, and evenness is Station 3 (Branta Tinggi), while for Mollusk is Station 4 (Raya Ambat Street). Both stations do not have a significant difference abiotic characteristics than other stations. We presume that the main factor causing higher diversity and ecological indices at Stations 3 and 4 is it has wider mangrove area and supported by denser vegetation that can provide better shelter for Crustacean and Mollusk. This also supported by Lee et al. (2017), which mentioned that the size of diversity, abundance, and species richness of mangrove biota may correlated with forest characteristics (e.g. tree density, biomass).

Compared with previous research that related to Crustacean and Mollusk diversity in Sampang and Pamekasan Districts, this study may be recorded one of the largest number of Crustacean and Mollusk species in location. Several research that has been conducted on the same station with this study that related to Crustacean and Mollusk diversity were: Pratiwi and Muhsoni (2021), in Taddan, Camplong Sub-District, Sampang District, whom studied mangrove ecotourism potential and found 5 Crustacean and 20 Mollusk species; Islamy and Hasan (2020), in Raya Ambat Street, Tlanakan Sub-District, Pamekasan District, whom studied the diversity of mangrove snails (Mollusca: Gastropoda) and found 15 species of it. Those research that has been carried out were limited to studying certain classes or genera, or only presents incomplete Crustacean and Mollusk biodiversity data because the focus of their study is not on diversity. However, data from previous research will be very helpful

in filling the gaps on this study. According to Cappenberg et al. (2021), the diversity of Crustaceans and Mollusks in mangrove ecosystems is always temporal and dynamic and depends on the response and pressure the ecosystem receives. One environmental factor that can affect the condition of the mangrove ecosystem is seasonal variation. According to information collected from residents around the study area, the mangrove area that is the sampling location will be heavily submerged by high tide during the rainy season. Surely, this could influence the structure of the Crustacean and Mollusk communities

The findings of this study may support the evidence from several research that stated mangrove ecosystems have high potential as biodiversity hotspots. Mangrove can provide stable and essential ecosystem services by protecting shoreline areas against tidal currents, waves, and eutrophication (Koh et al. 2018), which can be a crucial factor needed by intertidal organisms to support their life, such as Crustacean and Mollusks. Based on this study, several Crustaceans and Mollusk found, such as species from the family Ocypodidae and Potamididae, have certain associations with the environment of mangrove areas, so their presence can help provide an overview of conditions of the mangrove ecosystem in Sampang and Pamekasan Districts. Even so, to studied the diversity and population dynamics comprehensively, further research using more complex methods is needed, such as trapping and DNA analysis, as well as long-term monitoring to capture seasonal variations. So, a more holistic view of Crustacean and Mollusk complexity as a key role species on mangrove area can be provided.

In conclusion, the mangrove ecosystem in Sampang and Pamekasan Districts has certain similarities, i.e. both were composed by vegetation of *S. alba*, *A. marina*, *S. caseolaris*, and *R. mucronata*. Stations 1 and 3 had mangrove vegetation substrates that tend to be muddy, while Stations 2 and 4 had mangrove vegetation substrates that tend to be sandy. The environmental parameters measurement showed that the study area location had warm temperatures, wet soil, neutral pH, and relatively low salinity compared to Madura Strait. On study area location, as many as 32 Crustacean species was obtained consisting of 13 families from Decapoda and 1 family from Cirripedia. The most commonly found Crustacean species in study area location was *Balanus* sp. (barnacle), followed by *C. longitarsus* (common hermit crab). Based on calculations results, Crustacean diversity indices was 2.60 which means moderate, species richness indices was 4.05 which means high, evenness indices was 0.75 which indicates high evenness or stable community, and dominance indices was 0.10 which indicates no dominant species. Station 3 (Branta Tinggi) has the highest number of Crustacean species, diversity, species richness, and evenness among other station. Moreover, this study documented 24 Mollusk species from 17 families in study area location consisting of 14 Gastropoda, 9 Bivalvia, and 1 Polyplacophora. The most abundant Mollusk species and also occurred all stations were *P. alata* and *P. cingulata*. According to the calculation results, the Mollusk diversity indices was 2.61 which means moderate, species richness indices was 3.02 which means moderate, evenness indices was 0.82 which indicates high evenness or stable community, and dominance indices was 0.11 which indicates no dominant species. Station 4 (Raya Ambat Street) has the highest number of Mollusk species, diversity, species richness, and evenness among other station. The abundance of *Balanus* sp., *Clibanarius* sp., *P. alata*, and *P. cingulata* can be occurred mainly due to their intrinsic characters, reproductive behavior, growth rate, adaptability, and habitat suitability. The main factor causing higher diversity and ecological indices at Stations 3 and 4 is presumed by its wider mangrove area and supported by denser vegetation that can provide better shelter for Crustacean and Mollusk.

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