Distribution pattern of gastropods and physical chemical factors in the Kebumen mangrove forest, Indonesia

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Abstract. The mangrove area in Kebumen, Indonesia, is polluted from the jellyfish processing industry waste, which affects the distribution pattern of gastropods. This research aims to determine the distribution pattern of gastropods and provide important information for indicators of mangrove ecosystems changes. This study took place in Kebumen District, Central Java Province, Indonesia, from June to September 2018. Three sampling points were selected: Station A (high mangrove density), Station B (moderate mangrove density), and Station C (low mangrove density). The sampling method used for gastropods was collection from plots of 5x5 m. All gastropods in a plot were collected by hand and extracted from a 10 cm deep layer using a corer with 3 replications for each station. The environmental parameters were determined *in situ*: temperature, salinity, dissolved oxygen (DO), pH, and substrate type. The distribution of gastropods in the Kebumen mangrove forest has a clustered and even pattern. The highest abundance of gastropod species was found in Station 1, *Cerithidea alata* (209±9 ind 25 m^{-2}); in Station 2, *Pirenella cingulata* had the highest abundance (209±16 ind 25 m^{-2}), and in Station 3, *Neritina violacea* was most abundant (202±17 ind 25 m^{-2}). Physico-chemical factors that have a strong influence on gastropod density are water pH (6.92-7.93), dissolved oxygen (DO) (4.13-6.65 mg L^{-1}), substrate type (dust, clay, and sand), and phosphorous concentration (0.25-0.33%).
Key Words: evenness, grouping, mangrove, mollusk, physical chemical factors.

Introduction. Mangroves are one of the coastal ecosystems that have an important role in both ecologic and economic functions. The ecologic function of mangroves is translated to a source of feed for biota such as fish, crabs, shrimp, and others, sanctuaries for biota (Nordhaus et al 2009), a natural barrier blocking storms and tsunamis (Blankespoor et al 2017) and ecosystem carbon stocks (Kauffman et al 2011). The ecosystem is supported by the processes of physico-chemical factors and litter dynamics (Ariyanto et al 2019a), by decomposition processes (Ariyanto et al 2018a), by sources of macro and micro elements (Ariyanto et al 2019b) and sources of amino acids (Ningsih et al 2020). Mangroves provide an ecotourism area in terms of economic function (Surjanti et al 2020).

Gastropods are epifauna animals also found in mangrove ecosystems. Epifauna animals are invertebrates that have a habitat on the surface of sediments. Gastropods are generally epifauna and herbivores (Giesen et al 2006). Gastropods are very sensitive to local disturbances, such as decreased water quality and sediments, supported by limited gastropod mobility (Nordhaus et al 2009). Gastropods are members of the benthic community found in mangrove forests, such as *Cassidula nucleus* and *Cassidula angulifera* (Ariyanto et al 2018b) and *Cerithideopsilla djadjariensis* (Ariyanto et al 2020). Gastropods in a mangrove ecosystem act as a link in the food chain, decomposing litter (Silaen et al 2013), recycling nutrients that can increase primary productivity

(Thilagavathi et al 2013), and acting in primary productivity as a resource for herbivores (Cannicci et al 2008). Benthic communities are a sensitive indicator of changes in pollution levels, so they can be used as biomonitoring tools for evaluating environmental pollution (Bian et al 2016). This research aims to determine the distribution pattern of gastropods in some mangrove areas in Kebumen District, Central Java.

Material and Method. The study area was located in Kebumen District, Central Java Province, Indonesia, and the study was conducted from June to September 2018. Study sites were selected to include different levels of mangrove density exposure. The study area included 3 sampling points: Station 1 (ST1) (high mangrove density, >75%), Station 2 (ST2) (moderate mangrove density, 50-75%), and Station 3 (ST3) (low mangrove density, <50%) (Ministry of Environment 2004). The mangrove canopy was calculated with the hemispherical photography method at one point of taking photos (Jennings et al 1999; Korhonen et al 2007). The coordinates of ST1 are 7°43'08.33"S and 109°23'34.20"E; for ST2 they are 7°43'09.54"S and 109°23'32.77"E; and for ST3 they are 7°43'07.73"S and 109°23'31.47"E.

Gastropods. Sampling of gastropods in each location was conducted based on the Sasekumar method (Sasekumar 1974). The method consists in sampling gastropods in a plot measuring 5x5 m. All gastropods found in the plot were collected by hand and extracted from a 10 cm deep layer, using a corer. Sampling was conducted in three repetitions at each station. The gastropod samples obtained were all cleaned and placed in 5 kg plastic containers for each sampling point of the station. A 70% alcohol solution was added for initial preservation. The containers with samples were transported to the Research Center for Biology Laboratory, Indonesian Institute of Sciences, and Aquatic Laboratory, Jenderal Soedirman University, for identification with reference to Dance (1992) and Dharma (1988).

Environmental parameters. The environmental parameters were determined *in situ*. The physico-chemical parameters of the environment determined were: water pH, soil pH, air temperature, water temperature, salinity, dissolved oxygen (DO), phosphorus, nitrogen, organic matter, pyrite, dust, clay, and sand. Sediment was also collected to determine grain size and the content of organic material with 4 replications per station.

The grain size of sediments and the content of organic matter were determined with the Walkley-Black method (Global Soil Laboratory Network 2020) in the Soil Science Laboratory, State University of Surakarta. For the determination of texture, organic matter was oxidized with H_2O_2 and soluble salts were removed from the soil with HCl, while heating. The remaining material is a mineral and consist of sand, silt, and clay. The sand was separated by wet sieving, while dust and clay were separated by deposition according to Stoke's law.

Organic materials. 0.500 g of sediment were weighed and placed into a 100 mL volumetric flask. 5 mL of $K_2Cr_2O_7$ 1 N were added and the mix was shaked. 7.5 mL of concentrated H_2SO_4 were added, shaked, and left to stand for 30 minutes. The mix was diluted with ionized water, and allowed to cool. The next day, the absorbance of the clear solution was measured using a spectrophotometer at a wavelength of 561 nm. As a comparison, 0 and 250 ppm standards were made by pipetting 0 and 5 mL of 5000 ppm standard solution into a 100 mL volumetric flask.

Total phosphorus. 1 g of soil sample (<2 mm) was weighed and placed into a shaker. 20 mL of Olsen extract were added, and the new solution was mixed for 30 min and filtered. If the solution was cloudy, it was returned to the original filter. 2 mL of solution were extracted and pipetted into a test tube. 10 mL of phosphate dye reagent were added together with the standard series, mixed until homogeneity was achieved, and left for 30 min. The solution absorbance was measured with a spectrophotometer at 889 nm wavelength.

Total nitrogen. 0.5 g of soil sample (<0.5 mm) were weighed and placed into a digest tube. 1 g of selenium mixture and 3 mL of concentrated sulfuric acid were added. The mix was kept at a temperature of 350°C for 3-4 h. The destruction was complete when white steam appeared and a clear extract was obtained (after about 4 h). The tube was removed from the heat and cooled. The extract was diluted with ionized water (50 mL). The extract was mixed until reaching homogeneity and left overnight to allow the particles to settle. The extract was used for N measurement by distillation or colorimetric method.

Data analysis. The pattern of gastropod distribution was determined using the Morisita Deployment Index (Brower et al 1990). The gastropod similarity index was calculated. To see a general description of the gastropod community, a cluster analysis was employed. If there was a special grouping between stations, a SIMPER analysis was carried out to determine the similarity of each group and to know the gastropod species that contributed to the grouping.

Density is the number of individuals per unit area or volume, and was determined based on the formula of Krebs (2009):

$$Di = ni/L$$

Where: Di - mangrove density; ni - number of individual species i; L - plot area.

Species distribution. The distribution of mangroves and gastropods was determined by using the variance analysis variance based on Morisita index ($I\delta$) (Morisita 1959):

$$I\delta = [q \sum_{i=1}^{q} \mathrm{Xi}(\mathrm{Xi} - 1)]/[\mathrm{T}(\mathrm{T}\text{-}1)]$$

Where: $I\delta$ - Morisita index; xi - number of individual type X in all plots; q - number of plots; T - number of all individuals in all plots.

The interpretation of the distribution pattern in the research area is the following: if IM is 1, there is a random distribution pattern; if IM>1, there is a clustered distribution pattern; if IM<1, there is an even distribution pattern.

Statistial Analysis. The correlation between gastropod density and environmental physico-chemical factors was analyzed using BIO-ENV. All analyzes were carried out with the PRIMARY V5 software (Clarke & Warwick 2001).

Results and Discussion

Gastropod distribution. Table 1 shows the abundance of gastropods at the study site. 7 families of gastropods were found in this study: Assimineidae, Ellobiidae, Potamididae, Muricidae, Terebridae, Littorinidae and Neritidae. In SA1, *Cerithidea alata* (209±9 25 m^{-2}) had the highest abundance; in ST2, *Pirenella cingulata* had the highest abundance (146±9 25 m^{-2}); in SA3, *Neritina violacea* had the highest abundance (202±17 25 m^{-2}). The distribution pattern of each gastropod species can be observed from the results of the Morisita index analysis (Table 1). The gastropod distribution analysis shows that 4 species are distributed evenly: *Cassidula nucleus, Cassidula aurisfelis, Littoraria melanostoma,* and *Telescopium telescopium*. The other 17 species have a clustered distribution pattern.

Table 1

The abundance and distribution pattern of gastropods in Kebumen Mangrove Forest, Indonesia

Family	*Species*	*SA1*			*SA2*			*SA3*		
		K	*Id*	*Pattern*	*K*	*Id*	*Pattern*	*K*	*Id*	*Pattern*
Assimineidae	*Assimenia brevicula*	142 ±8	0.087	evenly distributed	115±9	0.134	evenly distributed	161±18	0.482	evenly distributed
Ellobiidae	*Cassidula nucleus*	30±5	0.004	evenly distributed	0±0			0±0		
	Cassidula aurisfelis	21±6	0.002	evenly distributed	6±3	0.0003	evenly distributed	0±0		
Potamididae	*Cerithidea quadrata*	78±6	0.026	evenly distributed	0±0			84±7	0.130	evenly distributed
	Cerithidea alata	209±9	0.188	evenly distributed	146±9	0.215	evenly distributed	158±13	0.464	evenly distributed
	Hastula sp.	136±3	0.079	evenly distributed	111±5	0.124	evenly distributed	0±0		
Muricidae	*Pirenella cingulata*	164±18	0.116	evenly distributed	201±16	0.409	evenly distributed	0±0		
Terebridae	*Littoraria melanostoma*	43±11	0.008	evenly distributed	0±0			0±0		
Littorinidae	*Littorina carinifera*	80±7	0.027	evenly distributed	47±4	0.022	evenly distributed	0±0		
	Neritina zigzag	48±6	0.0097	evenly distributed	33±2	0.0107	evenly distributed	0±0		
Neritidae	*Neritina violacea*	204±20	0.179	evenly distributed	193±14	0.377	evenly distributed	202±17	0.759	evenly distributed
	Nerita albicilla	77±6	0.025	evenly distributed	0±0			0±0		
	Nerita antiquata	44±4	0.008	evenly distributed	0±0			0±0		
	Neritina turita	46±3	0.008	evenly distributed	28±2	0.007	evenly distributed	64±3	0.075	evenly distributed
	Neritina lineata	57±3	0.012	evenly distributed	60±3	0.036	evenly distributed	0±0		
	Telescopium telescopium	0±0			0±0			25±6	0.011	evenly distributed
	Vittina variegata	63±1	0.016	evenly distributed	0±0			0±0	0.482	evenly distributed

Note: SA1 - station 1; SA2 - station 2; SA3 - station 3; K - abundance; Id - Morista index.

Patterns of a species grouping usually occur because of limiting factors for the existence of a population. A species grouping is caused by a tendency to defend itself from predators and other unfavorable factors. The limiting factors in the form of food availability and favorable habitat conditions can cause species grouping. Grouping behavior is caused by heterogeneous environments and reproductive models (Pemberton & Frey 1984). Tavares et al (2015) state that clustering is caused by habitat uniformity resulting in grouping in places with available feed. The pattern of distribution of biota is influenced by habitat parameters, which include physico-chemical factors, feed and the adaptability of a biota in an ecosystem (Nagelkerken et al 2008).

N. violacea, Neritina zigzag and *Telescopium telescopium* were found in the Kebumen mangrove forest. The species are also distributed in other places; *T. telescopism* was also found in the mangrove ecsosystem of coastal Banggi, Indonesia (Ariyanto 2019), *N. violacea* was found in China (Wang et al 2019), and *N. zigzag* in Segara Anakan, Indonesia (Pribadi et al 2010). The pattern of grouping similarities and contributions of gastropods was analyzed using multivariate analysis with two approaches (cluster), as presented in Figure 2.

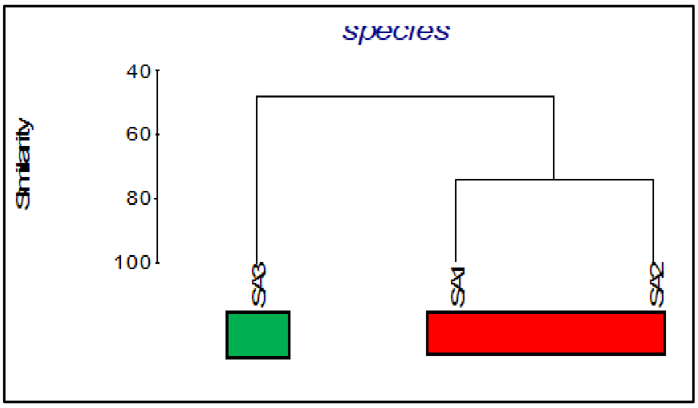

Figure 2. Grouping of gastropods based on clusters (SA1 - station 1; SA2 - station 2; SA3 - station 3).

By cluster analysis, gastropods form two groups, namely group A, present in ST1 and ST2 2, and group B, present in ST3. The pattern of distribution can result in increased competition between individuals in feeding and for space. Organisms that live in groups tend to be strong in competition. Group A has an average similarity of 74.37%. This shows that the gastropod grouping pattern has a high similarity. This can be seen from the contribution of *N. violacea* by 23.12%, *Ceritidhea alata* by 20.58%, *Pirenella cingulata* by 17.94%, and the three types of gastropods, *Hastula* sp., *Littorina carinifera* and *N. lineata*, which have the similarity value of 6.63%. The similarity of gastropods between stations from the similarity matrix results are presented in Table 2.

Table 2

The percentage of similarity index (%) of gastropods between Station 1, Station 2 and Station 3

No	*Stations*	*SA1*	*SA2*	*SA3*
1	SA1	-	-	-
2	SA2	73.93	-	-
3	SA3	46.63	48.96	-

Note: SA1 - station 1; SA2 - station 2; SA3 - station 3.

ST1 and ST2 have the highest species similarity, 73.93%. The average similarity of ST1 and ST2 shows a high homogeneity of species. Meanwhile, ST1 and ST3 have the lowest species similarity, 40.95%. The average similarity of ST1 and ST3 shows a low homogeneity of species, with a variety of contributions from each species.

The physico-chemical parameters are presented in Table 3. The correlation between gastropod density and physico-chemical factors that have the same value is 1.

Table 3

Physico-chemical parameters at each station

Parameter	*Station*		
	SA1	*SA2*	*SA3*
pH	6.92±0.13	6.93±0.13	7.93±0.02
Water Temperature °C	26.83±0.55	28.59±1.09	27.25±1.66
Salinity psu	20.58±0.53	21.14±0.54	28.08±0.61
DO mg L^{-1}	4.13±0.13	4.33±0.62	6.65±0.11
Total P (%)	0.25±0.06	0.23±0.07	0.33±0.09
Total N (%)	2.42±0.97	1.31±0.49	1.80±0.38
Organic materials (%)	31.81±19.36	20.00±0.83	16.77±2.59
Dust (%)	42.08	41.64	40.51
Clay (%)	44.67	44.21	42.80
Sand (%)	13.25	14.16	16.68

Note: SA1 - station 1; SA2 - station 2; SA3 - station 3; DO - dissolved oxygen; P – Phosphorous; N - Nitrogen.

Acidity (pH). The pH value in ST1, ST2 and ST3 are 6.92±0.13, 6.93±0.13, and 7.93±0.02, respectively. Compared to the two research stations, ST3 has the highest value. Moiseenko (2005) states that aquatic biota has a pH tolerance limit that varies and is influenced by various factors such as temperature, DO, organic matter, and others. Aquatic biota prefers pH between 7 and 8, and is sensitive to changes in pH (Abdel-Gawad & Mola 2014). pH values close to 5 or 9 are less favorable for some macrobenthos organisms.

Dissolved oxygen. The DO levels in ST1, ST2 and ST3 were 4.13±0.13 mg L^{-1}, 4.33±0.62 mg L^{-1}, and 6.65±0.11 mg L^{-1}, respectvely. Oxygen levels in the waters are influenced by temperature, bacterial activity, salinity, atmospheric pressure, season (Tian et al 2013), and water depth (Feresin et al 2010).

Substrate. Substrates contained clay, silk, and sand, in the following percentages in the 3 stations: SA1 - 42.8%, 44.67%, 13.25%; SA2 - 41.64%, 44.21%, 14.16%; SA3 - 40.51%, 41.80%, 16.68%. Skilleter & Warren (2000) explain that the basic substrate is a very important component for the life of benthic organisms. Substrate particle size is one of the main ecological factors influencing the macrobenthic community structure. The distribution of macrobenthos can clearly correlate with the type of substrate. Macrobenthos with digging properties (deposit eaters) tend to be abundant in mud sediments and soft sediments containing high organic matter (Dittmar & Lara 2001).

The substrate in a mangrove community is determined by geological and geomorphological processes that can change sediment characteristics, so that it is suitable for mangrove growth and development (Lovelock et al 2007). Sand substrate and coral fragments can be tolerated by the mangrove genus *Rhizophora*. *Rhizopora mucronata* has the ability to be more tolerant to sand and other more dense substrates (Lee et al 2014). The particle size and type of substrate is one of the ecological factors affecting organic matter and the spread of macrozoobenthos. The substrate can capture larger organic matter. Organic material can accumulate in muddy waters. Substrate and fine particles facilitate the absorption of organic matter. This type of soil occurs in areas affected by high and low tides, such as mangrove forests. Mangroves will retain seawater runoff, rich in sulfate and iron-containing clay deposits. Furthermore, Gao et al (2019) argue that soil texture and organic matter have a dominant role in mangrove distribution.

Phosphorous. Phosphorus and nitrogen are important nutrients in the waters. Both of these nutrients have limited existence and are needed for the growth of phytoplankton and diatoms (Boyd et al 2002). The phosphorus content was 0.25±0.06%, 0.23±0.07%

and 0.33±0.09% in ST1, ST2 and ST3, respectively. Phosphorus is used by phytoplankton in the form of orthophosphate and accumulates in the body of fish or shrimp through the food chain. Phosphorus not absorbed by phytoplankton will be bound by soil. The ability to bind is influenced by the clay content of the soil. The higher the content of clay is in the soil, the higher is the ability of the soil to bind phosphorus. Most phosphorus is bound by soil and a small portion is dissolved in water (Boyd et al 2002).

Nitrogen. The nitrogen in the study location was 2.42±0.97%, 1.31±0.49%, and 1.80±0.38% in ST1, ST2 and ST3, respectively. Nitrogen is an important ingredient in mangrove ecosystems. High and low nitrogen levels are related to the organic content of the mangrove ecosystem. The abundance of mangrove roots can increase the nitrogen content in the soil (Reef et al 2010; Goncalves Reis et al 2017). Organic nitrogen results from dead plankton and residues from aquatic animals that settle to the bottom. Nitrogen in soil organic material will be mineralized to ammonia and returned to the water, being reused by phytoplankton.

Temperature. The water temperatures were 28.17±2.17°C, 28.67±2.04°C, and 29±0.62°C, in ST1, ST2, and ST3, respectively. Temperatures were normal at the research locations, so they were suitable for the survival of marine organisms. Water temperature is a physical parameter that can affect the life patterns of aquatic biota such as distribution, abundance, and mortality (Brower et al 1990), changes in composition, abundance, and diversity of macrobenthos (Nagelkerken et al 2008), oxidation rate and oxygen solubility (Marshall & McQuaid 2020). Temperatures above 20°C will result in reduced gastropod activity. The optimal temperature for gastropod life is between 25 and 31°C (Marshall & McQuaid 2020). The temperature of a body of water is influenced by season, latitude, altitude of sea level, air circulation, cloud cover, water flow, and depth of water body, among others (Effendi 2003). Temperature can affect the activity of an organism either directly or indirectly. Direct influences manifest on growth, reproduction, and metabolism. Indirect effects influence the environment, and then the organism, like the processes of increasing accumulation of various substances in the water and decreasing oxygen levels. High temperatures can cause oxygen levels to decrease and pH to increase.

Salinity. Salinity values were 20.58±0.53 psu, 21.14±0.54 psu, and 28.08±0.61 psu in ST1, ST2 and ST3, respectively. Low salinity was observed in each station due to sampling in the rainy season. The occurrence of high and low tides caused fluctuations in the estuarine area. When the low mass of water entering the estuary comes from the river, it causes low salinity, while the high tide (the mass of water entering the estuary coming from the sea) increases the salinity. Changes in salinity are influenced by water circulation patterns, evaporation, rainfall, and river water flow. Veiga et al (2016) state that salinity can affect the variation of gastropods.

Organic materials. Some organic material comes from the debris of mangrove trees. The lowest organic matter content was in ST3, 16.77%. Station 3 is the least vegetated location, thus more lacking in mangrove litter. The station with high organic material is ST1, with 31.81%. ST1 is the station with the most mangrove vegetation. The organic matter is a food source for biota. Leaves, twigs, branches and plant roots form highly needed organic matter in the soil for the food chain, affecting the mangrove community structure. Reef et al (2010) state that mangrove litter is an important source of organic matter in the food chain in the aquatic environment. A content of forest organic matter higher than 20% shows that an area has a very high fertility rate, because falling mangrove leaves will accumulate on the bottom and decomposed. A higher density of mangroves produces more litter.

Conclusions. 17 species of gastropods were found. 4 species, *C. nucleus, C. aurisfelis, L. melanostoma,* and *T. telescopium* were evenly distributed. 13 species were distributed in groups, namely: *A. brevicula, C. quadrata, C. alata, Hastula* sp., *P. cingulata, L.*

carinifera, N. zigzag, N. violacea, N. albicilla, N. antiquata, N. turita, N. lineata, and *V. variegata*. Patterns of grouping occurred because of the limiting factor of mangrove density. The results of the SIMPER analysis of Group A show an average similarity of 74.37%. This shows that the gastropod grouping pattern has a high similarity. The contribution of *N. violacea* was of 23.12%, *Ceritidhea alata* 20.58%, *Pirenella cingulata* 17.94%. *Hastula* sp., *Littorina carinifera* and *N. lineata* had the same similarity value of 6.63%. The similarity of species between ST1 and ST2 was 73.93%. ST1 and ST3 had the lowest species similarity, 40.95%.

Acknowledgements. The authors express their gratitude to the Republic of Indonesia Ministry of Research, Technology, and Higher Education, who has provided a Domestic Postgraduate Education Scholarship (BPPDN).

Conflict of Interest. The authors declare that there is no conflict of interest.

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Received: 13 July 2020. Accepted: 26 October 2020. Published online: 02 July 2021.
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How to cite this article:
Wintah, Nuryanto A., Pribadi R., Sastranegara M. H., Lesatari W., Yulianda F., 2021 Distribution pattern of gastropods and physical chemical factors in the Kebumen mangrove forest, Indonesia. AACL Bioflux 14(4):1855-1864.