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The structure communities of gastropods in the permanently inundated mangrove forest on the north coast of Jakarta, Indonesia

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Abstract. *Hilmi E, Sari LK, Cahyo TN, Dewi R, Winanto T. 2022. The structure communities of gastropods in the permanently inundated mangrove forest on the north coast of Jakarta, Indonesia. Biodiversitas 23: 2699-2710.* The permanently inundated mangrove ecosystem support gastropods communities to live and grow. The gastropods communities require a mangrove ecosystem for feeding, spawning, nursing, distributing, and breading. The distribution of gastropod communities is shown by the number, association, and clustering of gastropods and is influenced by the potential of permanent water inundation. This research used association, clustering, and correlation methods to describe the distribution of gastropod communities. The results of this research showed that the mangrove ecosystem on the north coast of Jakarta was dominated by *Avicennia marina, Bruguiera gymnorrhiza, Calophyllum inophyllum, Cerbera manghas, Excoecaria agallocha, Nypa fruticans, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Sonneratia caseolaris, Terminalia catappa,* and *Thespesia populnea* with density between 20-2800 trees/ha. However, the gastropods communities in the mangrove ecosystem were dominated by *Cassidula angulifera, Cassidula aurisfelis, Cassidula plecotrematoides, Cassidula rugata, Ellobium aurisjudae, Ellobium gangeticum, Pythia plicata, Cerithidea obtusa, Cerithidea quoyii, and Melanoidessarius tuberculata* with abundance between 0.36 to 6.68 ind/m^2, 12 pairs positive association from 78 pairs, had uniform distribution (Moroshita index 0-0.87), and two clusters.

Keywords: Abundance, association, distribution index, diversity, gastropod cluster

INTRODUCTION

Jakarta's mangrove forests are located on the north coast, growing in an estuarine and brackish water environment, and are almost permanently flooded (Onrizal et al. 2005; Yanuartanti et al. 2015; Hilmi et al. 2021c,a). The forest gets freshwater supplies from the Citarum, Bekasi, and Ciliwung rivers (Onrizal et al. 2005; Yanuartanti et al. 2015; Hilmi et al. 2017a, 2022b,a). Permanent inundation influences the mangrove ecosystem functions as aquatic habitats, including benthic fauna (e.g., Gastropods). The mangrove ecosystem on the north coast of Jakarta has characteristic permanent water inundation that impacts the potential of environmental services, including habitat for aquatic organisms (Lapolo et al. 2018; Belhiouani et al. 2019; Nurhayati et al. 2021; Purnama et al. 2022). The mangrove ecosystem on the north coast of Jakarta supports feeding grounds, nursery grounds, and spawning grounds of aquatic organisms (Andriyani et al. 2020; Hilmi et al. 2020, 2021c; Nurhayati et al. 2021; Rahman et al. 2021), including gastropods communities. The gastropods communities on the north coast of Jakarta are estimated to have high diversity and wide distribution.

Mangrove ecosystems are home to mangrove plants, gastropods, mollusk microphytobenthos, and phytoplankton (Teoh et al. 2018; Susintowati et al. 2019; Tebiary et al. 2022), making it as the most productive ecosystems, including litter production (Saleky et al. 2016; Sihombing et al. 2017; Teoh et al. 2018; Rahman et al. 2021). Litter production provides food sources for benthic communities, including gastropods. Along with food availability, physical factors, competition, and predations control gastropod species association and distribution (Peng et al. 2017; Nurhayati et al. 2021; Rahman et al. 2021; Purnama et al. 2022). Gastropods also play an important ecological role as detritivores, utilizing mangrove litter as their food source (Lazzeri 2017; Belhiouani et al. 2019; Nurhayati et al. 2021). Therefore, gastropod communities may associate healthy ecosystems and organic matter consumption (Alam et al. 2021; Rahman et al. 2021; Purnama et al. 2022).

Gastropods are shelled, snails, and naked slugs animals (some of the types of gastropods are organisms with a single shell, spiral shape, various colors, and bends from the embryonic stage, using a stomach to move). The gastropods belong to the phylum Mollusca (Masagca et al. 2010; Saleky et al. 2016; Peng et al. 2017; Belhiouani et al. 2019; Nurhayati et al. 2021; Purnama et al. 2022). Gastropods have a wide distribution in tidal areas to 8200 m of water depth (Masagca et al. 2010; Saleky et al. 2016; Peng et al. 2017; Belhiouani et al. 2019; Nurhayati et al. 2021; Purnama et al. 2022). As herbivores and detritivores, gastropods have an important role in supporting the breaking down litter process into smaller parts of organic matter (Saleky et al. 2016; Setyawati et al. 2019; Susintowati et al. 2019; Tebiary et al. 2022), have an activity to turn leaves and twigs into small pieces to support feeding activity of microorganisms. Basically, the abundance and distribution of gastropods communities are determined by many factors like as the composition of mangrove species, water inundation, food availability, predation, and competition (Lu et al. 2013; Abdullah and Lee 2017; Lapolo et al. 2018; Bathmann et al. 2021; Rahman et al. 2021).

The gastropods communities in the mangrove ecosystem have feeding activities on the ground at low tide and climb stem 2-3 m before the arrival of sea tide, settling about 40 cm above the level of high inundation (Lazzeri et al. 2014; Lazzeri 2017; Belhiouani et al. 2019; Nurhayati et al. 2021). Gastropod distribution can also be used as bio-indicators for pollution monitoring because they have the ability to absorb heavy metals and others. Gastropods are also filter feeders that take up metals from the water column, food, and organic and inorganic particulate matter. Gastropods have the ability to accumulate large quantities of heavy metals and other contaminants (Bhandari et al. 2021). Gastropods must adapt to environmental stressors with morphological change, physiological, or behavioral (Reis et al. 2021), including distribution activity with association and cluster pattern (Lapolo et al. 2018; Nurhayati et al. 2021; Rahman et al. 2021; Reis et al. 2021). Variations influence this activity in temperature, humidity, water, inundation, physicochemical conditions, pH, and salinity (Peng et al. 2017; Susintowati et al. 2019; Reis et al. 2021; Tebiary et al. 2022).

The association and clustering are shown by the frequency degree of two species' life in location because of similar resources and environment (Belhiouani et al. 2019; Hilmi et al. 2021c; Nurhayati et al. 2021; Rahman et al. 2021). These relation types of gastropods also describe the similar or different adapting patterns of gastropods to grow and live using the mangrove resources and are developed using the similarity, dissimilarity, distance, and specific correlation among species (Datta and Deb 2017; Hilmi et al. 2021c,b, 2022b; Vázquez-González et al. 2021). This concept uses distance analysis and is known as the Euclidian distance index using hierarchical and non-hierarchical methods (Njana 2020; Hilmi et al. 2021b,c).

As a limiting factor, the permanently inundated mangrove ecosystem influences the composition, configuration, behavior, growth, survival, occurrence, and distribution of gastropods (Cacabelos et al. 2021; Reis et al. 2021). The permanent water inundation also impacts habitat preferences, biotic interactions, and abiotic disturbances and improves gastropods' clustering, distribution, and association. But gastropods also have limitation of adaptation, desiccation, and environmental stresses such as shell-lifting, shell-standing, towering, aggregation of conspecifics, or habitat selection (Lazzeri 2017; Moisez et al. 2020). This paper aims to analyze the association and clustering of gastropods communities in the permanently inundated mangrove ecosystem on the North Coast of Jakarta, Indonesia.

MATERIALS AND METHODS

Research area and periods

This research was conducted between October 2021-February 2022 on the north coast of Jakarta at six stations (high and permanently water inundation) (Hilmi et al. 2021c, 2022b) that were mangrove ecotourism (station 1), Angke preservation 1 (station 2), Angke preservation 2 (station 3), Angke preservation 3 (station 4), Arboretum area (station 5) and Galatama Area (Tol Sediatmo) (Station 6) (Figure 1, Table 1). The sampling plots were determined by cluster sampling using the potential of water inundation and mangrove density as main variables.

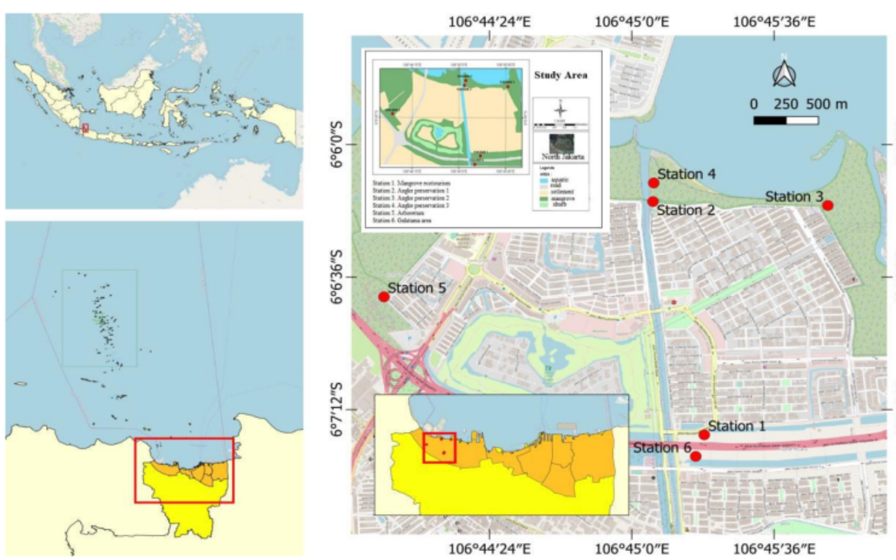

Figure 1. The research station in north coast of Jakarta, Indonesia

Mangrove density

Mangrove density was determined by the equation of vegetation analysis (Hilmi et al. 2017b; Hilmi 2018; Xiong et al. 2018; Cooray et al. 2021):

$$\text{Mangrove tree density} = \frac{\text{Tree number of mangrove speies}}{\text{area}}$$

The analysis of tree density (diameter > 4cm) adopted the line transect method with a sampling plot of 10m x 10m. The tree density distribution of the plant ecosystem uses Hilmi et al. (2020).

Sampling of gastropods

Gastropod samples were collected in five plots of 1m x 1m nested in the 10m x 10m plot (Figure 2). This research had six stations with 5 plots/in each station. The number of gastropod sample plots were 150 samples plot. The gastropod's sampling time activity can be shown in Table 2. All gastropods found in the plots were hand-picked and preserved in alcohol solutions of 70%. The samples were grouped based on ecological niches, i.e., treefauna (found on the roots, stems, and leaves) and epifauna (sediment surfaces). Observation of treefauna was limited to up to 2 meters from the ground surface or the highest tide level (Belhiouani et al. 2019; Susintowati et al. 2019; Nurhayati et al. 2021; Rahman et al. 2021). The gastropods variables were the number of gastropods/in each sampling plot, the abundance of gastropods/in each station, the number of plots containing gastropod species, and environmental variables. The gastropod sampling activity was divided into 5 teams (2-3 people/team). Sampling time is 3 hours every morning for 5 days/plot.

Table 1. Description of six observation stations across four study areas on the north coast of Jakarta, Indonesia

Stations	Site	Utilization of mangrove ecosystem	Coordinates	
			Latitude (S)	Longitude (E)
1	Mangrove ecotourism	Ecotourism area	06°07'18.88"	106°45'18.37"
2	Angke perservation 1	River preservation and greenbelt	06°06'15.50"	106°45' 05.41"
3	Angke perservation 2	River preservation and greenbelt	06°06'16.556"	106°45'49.608"
4	Angke perservation 3	River preservation and greenbelt	06°06'16.614"	106°45'49.619"
5	Mangrove arboretum	Tidal fooding	06°06'41.386"	106°43'57.374"
6	Galatama area	Greenbelt	06°07'24.733"	106°45'16.124"

Table 2. The gastropods sampling time on the north coast of Jakarta, Indonesia

Stations	Plot	Season	
		Dry season	Rainy season
Mangrove ecotourism	Plot 1	3 hours in the morning/ (team1)/5days	3 hours in the morning/ (team1)/5days
	Plot 2	3 hours in the morning/ (team2)/5days	3 hours in the morning/ (team2)/5days
	Plot 3	3 hours in the morning/ (team3)/5days	3 hours in the morning/ (team3)/5days
	Plot 4	3 hours in the morning/ (team4)/5days	3 hours in the morning/ (team4)/5days
	Plot 5	3 hours in the morning/ (team5)/5days	3 hours in the morning/ (team5)/5days
Angke perservation 1	Plot 1	3 hours in the morning/ (team1)/5days	3 hours in the morning/ (team1)/5days
	Plot 2	3 hours in the morning/ (team2)/5days	3 hours in the morning/ (team2)/5days
	Plot 3	3 hours in the morning/ (team3)/5days	3 hours in the morning/ (team3)/5days
	Plot 4	3 hours in the morning/ (team4)/5days	3 hours in the morning/ (team4)/5days
	Plot 5	3 hours in the morning/ (team5)/5days	3 hours in the morning/ (team5)/5days
Angke preservation 2	Plot 1	3 hours in the morning/ (team1)/5days	3 hours in the morning/ (team1)/5days
	Plot 2	3 hours in the morning/ (team2)/5days	3 hours in the morning/ (team2)/5days
	Plot 3	3 hours in the morning/ (team3)/5days	3 hours in the morning/ (team3)/5days
	Plot 4	3 hours in the morning/ (team4)/5days	3 hours in the morning/ (team4)/5days
	Plot 5	3 hours in the morning/ (team5)/5days	3 hours in the morning/ (team5)/5days
Angke perservation 3	Plot 1	3 hours in the morning/ (team1)/5days	3 hours in the morning/ (team1)/5days
	Plot 2	3 hours in the morning/ (team2)/5days	3 hours in the morning/ (team2)/5days
	Plot 3	3 hours in the morning/ (team3)/5days	3 hours in the morning/ (team3)/5days
	Plot 4	3 hours in the morning/ (team4)/5days	3 hours in the morning/ (team4)/5days
	Plot 5	3 hours in the morning/ (team5)/5days	3 hours in the morning/ (team5)/5days
Mangrove arboretum	Plot 1	3 hours in the morning/ (team1)/5days	3 hours in the morning/ (team1)/5days
	Plot 2	3 hours in the morning/ (team2)/5days	3 hours in the morning/ (team2)/5days
	Plot 3	3 hours in the morning/ (team3)/5days	3 hours in the morning/ (team3)/5days
	Plot 4	3 hours in the morning/ (team4)/5days	3 hours in the morning/ (team4)/5days
	Plot 5	3 hours in the morning/ (team5)/5days	3 hours in the morning/ (team5)/5days
Galatama area	Plot 1	3 hours in the morning/ (team1)/5days	3 hours in the morning/ (team1)/5days
	Plot 2	3 hours in the morning/ (team2)/5days	3 hours in the morning/ (team2)/5days
	Plot 3	3 hours in the morning/ (team3)/5days	3 hours in the morning/ (team3)/5days
	Plot 4	3 hours in the morning/ (team4)/5days	3 hours in the morning/ (team4)/5days
	Plot 5	3 hours in the morning/ (team5)/5days	3 hours in the morning/ (team5)/5days

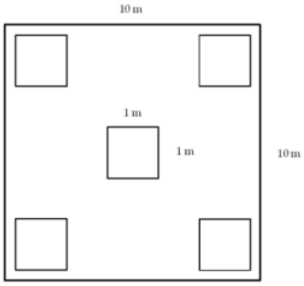

Figure 2. Plot arrangement for gastropod data collection

Species abundance of gastropod species be calculated by the number of individual gastropods found with the following formula (Lapolo et al. 2018; Dencer-Brown et al. 2020; Nurhayati et al. 2021; Purnama et al. 2022):

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

Where:
A: Abundance (ind/m^2)
Xi: Number of individuals of the i-th type (individuals)
Ni: Area of the i-th type of transect found (m^2)

Association analysis

The analysis of mangrove associations using the contingency tables is calculated by the *Chi-square* formula (Ludwig and Renold 1988; Hilmi et al. 2021c; Rahman et al. 2021).

$$\textit{Chi-square} = \frac{N(ad-bc)^2}{(a+b)(a+c)(c+d)(b+d)}$$

Where:
a: the number of plots containing gastropod species A and B
b: the number of plots containing gastropod species A only
c: the number of plots containing gastropod species B only
d: the number of plots that do not have gastropod species A and B
N: The number of plots.

$$E(a) = \frac{(a+b)(a+c)}{N}$$

If the score of a>E (a) is defined as a Positive association,
If the score of a< E (a) is defined as a Negative association.

Distribution analysis

The analysis of gastropods distribution was determined by the Morisita distribution index (Lapolo et al. 2018; Njana 2020; Nurhayati et al. 2021):

$$Id = \frac{n\,(\sum x^2) - n}{N(N-1)}$$

Where:
Id: Morisita distribution index
n: Number of plots
N: Total number of gastropods
x^2: Sum of the individual squares of the plot

Where the results of this distribution are grouped into 3 criteria, there are:
Id < 1: Gastropod distribution is uniform
Id = 1: The distribution of gastropods is random
Id > 1: The distribution of gastropods is clustered

Clustering analysis

Cluster analysis is developed using similarity and dissimilarity analysis through Euclidian distance analysis (Ludwig and Renold 1988; Hilmi et al. 2021c). The analysis of the mangrove cluster followed mathematical manipulation using excel software and was justified by Premiere software. The cluster analysis followed stages:

Stage 1

$$ED_{jk} = \sqrt{\sum_{i=1}^{s}(xij - xik)^2}$$

Stage 2

$$D\,(j,k)h = \alpha_1\, D(j,h) + \alpha_2\, D(k,h) + \beta\, D(j,k)$$

Stations	2	3	4	..	n
1	ED_{12}	ED_{13}	ED_{14}		
2		ED_{23}	ED_{24}		
3			ED_{34}		
			...		
N			EDn 4		

Notes:
Ed*jk* : Euclidean Distance
i : species
X*ij* : density in the station-*j*
X*ik* : density in the station-*k*
D : Distance
α1 : 0.625
α2 : 0.625
β : -0.25

RESULTS AND DISCUSSION

Mangrove density

The mangrove density on the north coast of Jakarta was affected by the level of permanent water inundation (Hilmi et al. 2021c, 2022b). The mangrove species must have good adaptation to reduce the impact of the permanent water inundation. The permanent water inundation will cause differences in species dominance and distribution (Lu et al. 2013; Bathmann et al. 2021; Hilmi et al. 2021b,c, 2022a,b). The water inundation also influenced community structures of the mangrove ecosystem as a mangrove response to reduce the impact of tidal inundation, water salinity, and freshwater potential (Lu et al. 2013; Bathmann et al. 2021; Hilmi et al. 2021b,c, 2022a,b). The mangrove ecosystem has a specific structure and distribution (both of existence of mangrove species, the height and trees density, and variation of primary productivity) as coastal protection and preservation to reduce the impact of tidal and high waves (Hilmi et al. 2015; Kantharajan et al. 2018; Domínguez-domínguez et al. 2019; Bathmann et al. 2021). The levels of water inundation and tidal waves trigger the mangrove environment to support tree growth and structure (Abdullah and Lee 2017; Bathmann et al. 2021). Basically, the permanent water inundation also influences the requirement for freshwater supply to support the survival of mangrove species (Bathmann et al. 2021; Hilmi et al. 2021c, 2022b). The mangrove density level in permanently inundated seawater areas on the north coast of Jakarta can be seen in Table 3.

Table 3 shows that the mangrove density on the north coast of Jakarta was 740 ± 87.1-1800 ± 374.2 trees/ha, with a density class between rare-medium (Hilmi et al. 2019). The dominant species are *Avicennia marina, Rhizophora apiculata, Rhizophora mucronata*, and *Rhizophora stylosa*, which have a high ability to grow and develop in the mangrove ecosystem with permanently inundated between 0.5-2m, and salinity between 5-8 ppt with a pH between 4-7. According to Hilmi et al. (2017a), Hilmi et al. (2021a,b,c), and Hilmi et al. (2022a), the coastal areas on the north coast of Jakarta have good suitability for supporting mangrove growth. Still, water inundation has become the limiting factor for mangrove growth.

Bathmann et al. (2021) also describe that mangrove has the ability to develop mangrove zonation to reduce the impact of tidal inundation, water salinity, and limited availability of nutrients because mangrove species have salt and water excreting gland and accumulating gland which as a specific metabolism in permanent water inundation area (Win et al. 2019; Hilmi et al. 2021c, 2022b; Kumbier et al. 2021). This zoning was developed as an adaptation pattern of mangrove species to reduce driving factors such as salinity, soil structure, soil aeration, and nutrient availability, as well as biotic factors such as physiological tolerance, distribution, successional predation and competition (Hoppe-Speer et al. 2011; Yang et al. 2013; Win et al. 2019; Hilmi et al. 2021c, 2022b; Kumbier et al. 2021).

Table 3. The density levels and dominant types of mangrove trees on the north coast of Jakarta, Indonesia

Stations	Mangrove density (tree ha^{-1})	Species dominance	Habitat properties
Muara Angke ecowisata	1800 ± 374	*Avicennia marina, Bruguiera gymnorrhiza, Calophyllum inophyllum, Excoecaria agallocha, Nypa fruticans, Rhizophora mucronata, Rhizophora stylosa, Sonneratia caseolaris, Terminalia catappa, Thespesia populnea*	Water inundation: 0-0.5 m Salinity: 5-7 ppt pH: 5.5-6.5
Muara Angke preservation 1	1020 ± 162	*Avicennia marina, Bruguiera gymnorrhiza, Cerbera manghas, Excoecaria agallocha, Rhizophora mucronate, Rhizophora stylosa, Sonneratia caseolaris, Terminalia catappa*	Water inundation: 0.6-1 m Salinity: 5-8 ppt pH: 5-6.3
Muara Angke preservation 2	740 ± 87	*Avicennia marina, Nypa fruticans, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Sonneratia caseolaris*	Water inundation: 1.5-2 m Salinity: 6-8 ppt pH: 5-6.2
Muara Angke accretion	980 ± 257	*Avicennia marina, Excoecaria agallocha, Rhizophora stylosa, Sonneratia caseolaris, Thespesia populnea*	Water inundation: 1.7-2.0 Salinity: 6-8 ppt pH: 5-6.2
Muara Angke arboretum	1640 ± 435	*Avicennia marina, Rhizophora mucronata, Rhizophora stylosa*	Water inundation: 1.0-1.5 Salinity: 5-6 ppt pH: 5-6.3
Muara Angke galatama	880 ± 258	*Avicennia marina, Rhizophora mucronata, Rhizophora stylosa, Terminalia catappa*	Water inundation: 0-0.5 m Salinity: 5-6 ppt pH: 4.9-5.8

The abundance of gastropods

The north coast of Jakarta found 13 types of gastropods found, which were *Cassidula angulifera, Cassidula aurisfelis, Cassidula plecotrematoides, Cassidula rugata, Ellobium aurisjudae, Ellobium gangeticum, Pythia plicata, Cerithidea obtusa, Cerithidea quoyii, Melanoides tuberculata, Nassarius reticulatus, Neritina violacea,* and *Pila ampullacea* (Figure 3). The species of gastropods were divided into 6 families, 8 genera, and 13 species. The gastropod families on the north coast of Jakarta were Ellobiidae, Potamididae, Thiaridae, Nassarius, Neritidae, and Ampullariidae. Based on the life types of gastropods are divided into three classes, namely life in mangrove trees (treefauna), life on the surface of muddy substrates (epifauna), and life in the substrate (infauna) (Putro et al. 2015; Teoh et al. 2018; Belhiouani et al. 2019; Susintowati et al. 2019; Bhandari et al. 2021; Nurhayati et al. 2021; Reis et al. 2021), The life type of gastropods found in the north coast of Jakarta divided into epifauna and treefauna gastropods (Table 4).

On the north coast of Jakarta, the communities of gastropods were divided into two classes: the epifauna gastropods (life on muddy substrate surfaces) and treefauna gastropods (found on the roots of mangrove trees and dead mangrove trunks). The activity of epifauna gastropod is influenced by the surface of the mangrove ecosystem and the high potential of organic matter. Meanwhile, treefauna gastropods live in mangrove trees and mangrove stem because they are not resistant to water salinity and tides. For that, the gastropod must have a moving ability to avoid the impact of permanent inundation (Teoh et al. 2018; Belhiouani et al. 2019; Rahman et al. 2021; Reis et al. 2021).

Table 4 also showed that the abundance of gastropod species on the north coast of Jakarta had ranged between 0.36 to 6.68 ind/m^2. *Pila ampullacea* had the best abundance of gastropods, with an abundance of approximately 6.68 ind/m^2, while the lowest abundance was *Ellobium aurisjudae*, with an abundance of approximately 0.36 ind/m^2.

The distribution of gastropods families in north coast of Jakarta showed that The Ellobiidae family had the best abundance of gastropods, consisting of; *C. angulifera, C. aurisfelis, C. plecotrematoides, C. rugata, E. aurisjudae, E. gangeticum,* and *P. plicata*. The Ellobiidae family had the ability to dominate the mangrove ecosystem on the north coast of Jakarta because of the existence of mud clay in the mangrove substrate. According to Belhiouani et al. (2019), Bhandari et al. (2021), Cacabelos et al. (2021), and Nurhayati et al. (2021), some gastropods species prefer to live in mud clay substrates because they have the lot of organic matter and the smoother characteristics and high potential of organic matter settle. Belhiouani et al. (2019), Susintowati et al. (2019); Nurhayati et al. (2021), and Purnama et al. (2022) write that the Ellobiidae family is a native of species of mangrove gastropods, has a wide distribution, life on muddy substrates and the roots and stems of mangroves.

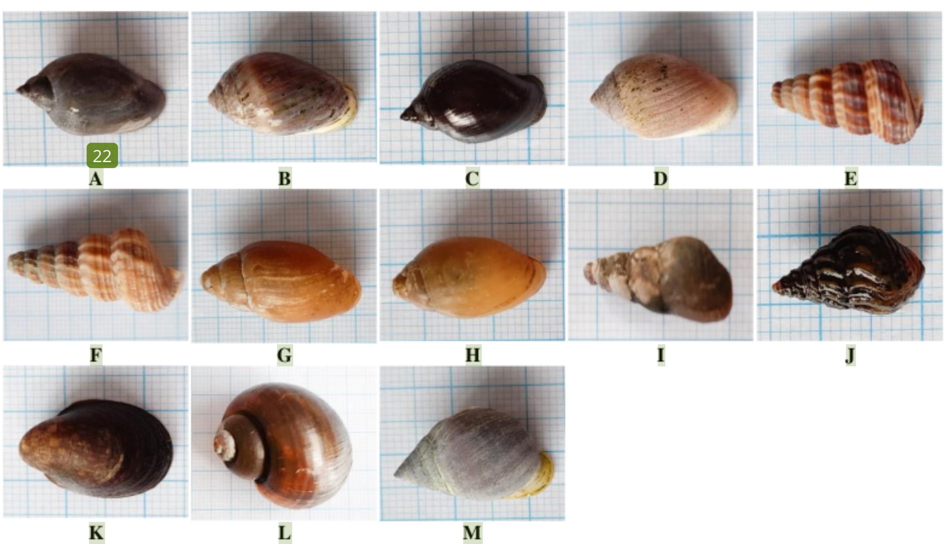

Figure 3. Species of gastropods in north coast of Jakarta, Indonesia. Note: A. *Cassidula angulifera,* B. *Cassidula aurisfelis,* C. *Cassidula plecotrematoides,* D. *Cassidula rugata,* E. *Ellobium aurisjudae,* F. *Ellobium gangeticum,* G. *Pythia plicata,* H. *Cerithidea obtusa,* I. *Cerithidea quoyii,* J. *Melanoides tuberculata,* K. *Nassarius reticulatus,* L. *Neritina violacea,* M. *Pila ampullacea*

Table 4. The abundance of gastropods in mangrove habitat of north coast of Jakarta, Indonesia

Family	Genus	Species	Abundance (gastropod/m²) Stations						Total		
			1	2	3	4	5	6		Epifauna	Tree fauna
Ellobiidae	Cassidula	*Cassidula angulifera*	-	-	-	-	-	0.87	0.87	✓	
		Cassidula aurisfelis	-	-	1.85	-	-	-	1.85	✓	✓
		Cassidula plecotrematoides	-	-	-	-	-	0.9	0.90	✓	✓
		Cassidula rugata	-	-	1.07	-	-	-	1.07	✓	✓
	Ellobium	*Ellobium aurisjudae*	-	-	-	0.36	-	-	0.36	✓	✓
		Ellobium gangeticum	-	-	-	0.52	-	-	0.52	✓	✓
	Pythia	*Pythia plicata*	-	-	-	0.78	-	-	0.78	✓	
Potamididae	Cerithidea	*Cerithidea obtusa*	-	-	-	-	1.12	-	1.12	✓	✓
		Cerithidea quoyii	-	-	-	-	0.65	-	0.65	✓	✓
Thiaridae	Melanoides	*Melanoides tuberculata*	0.42	1.45	-	0.57	-	-	2.44	✓	
Nassarius	Nassarius	*Nassarius reticulatus*	-	-	-	1.88	-	-	1.88	✓	
Neritidae	Nerita	*Neritina violacea*	-	-	0.82	-	-	-	0.82	✓	✓
Ampullariidae	Pila	*Pila ampullacea*	3.39	1.15	-	-	-	2.14	6.68	✓	
Total			3.81	2.60	3.74	4.11	1.77	3.91	19.94		
Deviation standard			2.10	0.21	0.54	0.61	0.33	0.72	0.91		

The association of gastropods

The association of gastropods on the north coast of Jakarta could be seen in Figure 4. The gastropod association had 78 species pairs, consisting of 66 pairs that did not have an association and 12 pairs that had a positive association. The positive association was dominated by *C. angulifera* with *C. plecotrematoides, E. aurisjudae* with *E. gangeticum, E. aurisjudae* with *N. reticulatus, E. aurisjudae* with *P. plicata, E. gangeticum* with *Nassarius reticulatus, E. gangeticum* with *P. plicata, N. reticulatus* with *P. plicata, C. aurisfelis* with *C. rugata, C. aurisfelis* with *N. violacea, C. rugata* with *N. violacea, C. obtusa* with *C. quoyii,* and *C. quoyii* with *N. violacea*. The positive association was shown by living together gastropods in dead trees and stems, having similar activity to avoid predators, reducing the impact of high tidal inundation, and similar feeding patterns and feeding activity (Teoh et al. 2018; Belhiouani et al. 2019; Moisez et al. 2020; Nurhayati et al. 2021; Purnama et al. 2022). This association pattern shows the similarity of habitat, diet, or reducing the activity of unfavorable conditions (Hilmi et al. 2015, 2021c; Datta and Deb 2017; Pham et al. 2019).

The positive association of gastropods shows the relation between species to live together, interplay, not disturb, not compete with each other, and require similar resources to support feeding and growth activity (Masagca 2009; Wang et al. 2018; Dencer-Brown et al. 2020). Whereas non-associative relationships describe gastropods' different activity, resource requirements, and responses to environment changes and are rarely found together (Nurhayati et al. 2021; Rahman et al. 2021; Purnama et al. 2022). The non-associative also be shown by the potential of facultative gastropods, visitor gastropods, or recessive gastropods. And this data showed that on the north coast of Jakarta, gastropods could be grouped into three types that were native mangrove gastropods, facultative gastropods, and visitor gastropods (Teoh et al. 2018; Susintowati et al. 2019; Dencer-Brown et al. 2020; Nurhayati et al. 2021; Purnama et al. 2022).

The distribution of gastropods

The Morishita index results described that the distribution pattern of gastropods on the north coast of Jakarta was categorized as uniform distribution (0-0.87) (Table 5). The distribution pattern of gastropods can be developed by feed activity, food availability, potential substrate, and ecological factors of physics, chemistry, and biology. The distribution of gastropods described growth, life activity, adaptation strategies, and biological interactions between gastropods in the mangrove ecosystem (Saucy et al. 2016; Belhiouani et al. 2019; Dencer-Brown et al. 2020; Nurhayati et al. 2021; Reis et al. 2021).

The distribution of gastropods on the north coast of Jakarta was strongly influenced by the height and duration of tidal inundation (Belhiouani et al. 2019; Hilmi et al. 2021c. 2022b; Nurhayati et al. 2021). The tidal inundation that caused most of the mangrove areas in north coast of Jakarta could be categorized as an ecosystem with permanent water inundation (Hilmi et al. 2021c, 2022b). The water inundation will impact organisms' adaptation and distribution patterns (Lazzeri 2017; Hilmi et al. 2021b, 2022b). The gastropods distribution on the north coast of Jakarta had a uniform trend. Basically, the cluster distribution of populations in nature will not be uniform. Another factor influencing gastropod distribution is high competition between individuals in a non-ideal environment, including domestic waste and industry contaminants (Wolswijk et al. 2020; Rahman et al. 2021). The gastropods require high adaptations to survive, live, and grow in this condition (Lazzeri et al. 2014; Lazzeri 2017).

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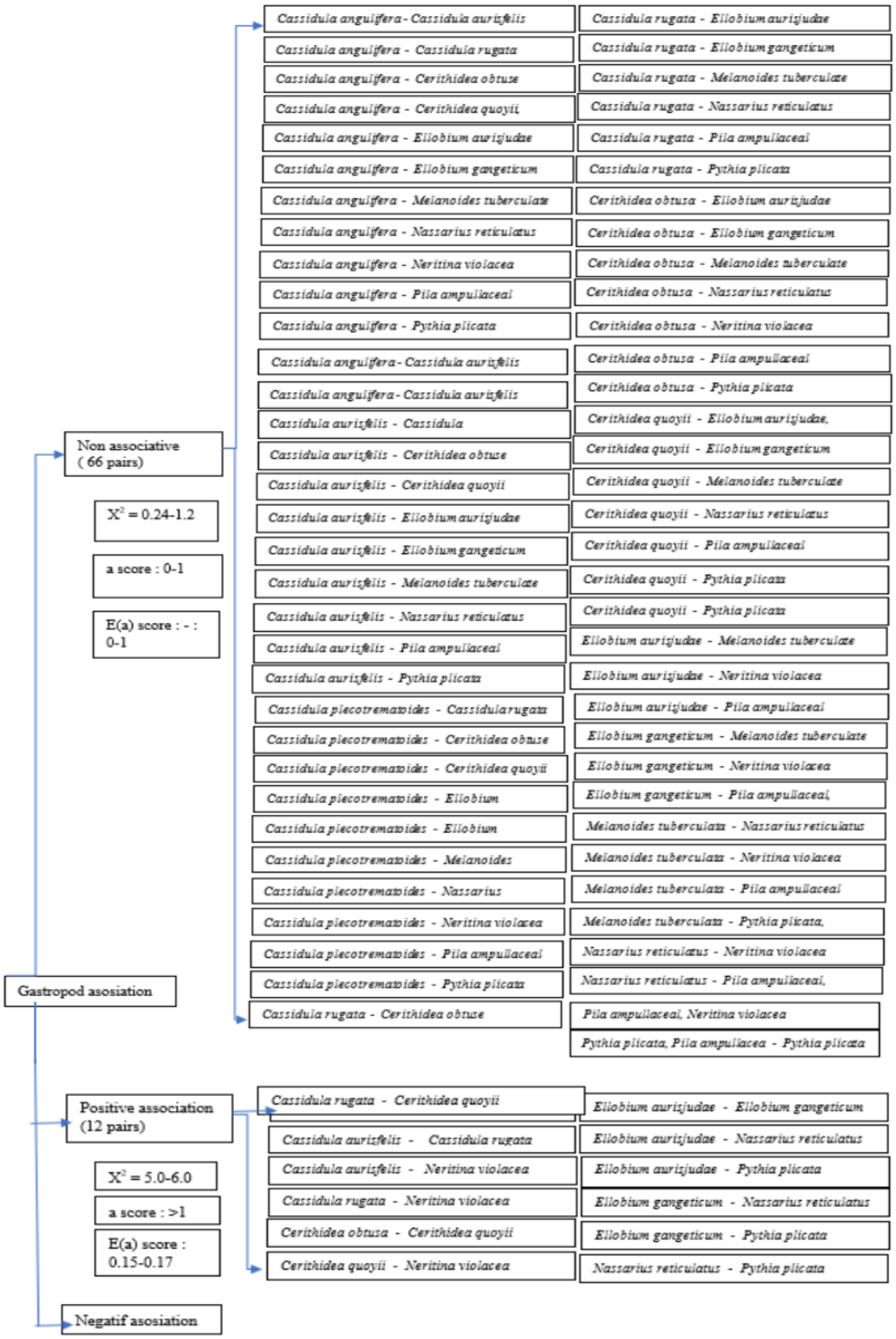

Figure 4. The association of mangrove gastropods

The genus of *Cassidula* is the best dominant gastropod on the north coast of Jakarta because of its ability to adapt and choose the mangrove ecosystem as its habitat. The *Cassidula* can grow in mangrove areas and be dominated by the *Avicennia marina* permanent water inundation and a mud clay-substrate. The *Avicennia marina* is a suitable tree to support gastropods' life and growth. According to Sihombing et al. (2017), Dencer-Brown et al. (2020), Rahman et al. (2021) and Bhandari et al. (2021), the existence and ecological succession of *Avicennia marina* and mud clay-substrate is a good factor in supporting gastropods' life and growth.

The clustering of Gastropods

Clustering of gastropods' habitat

The clustering of gastropods' habitats could be seen in Figure 5, which describes stations 2, 5, and 3 had similar habitats (based on permanent water inundation). Potential gastropods in these stations also were dominated by *C. obtusa*. *Cerithidea quoyii*. *M. tuberculata*. *and P. ampullaceal* abundance between 1020 individuals/ha and 1640 individuals/ha. Whereas stations 1 and 4 had different high habitats because only the *M. tuberculata* found life together in this station. Stations 1 and 4 also differed in gastropod abundance because station 4 is occupied by many gastropods while station 3 is not.

Basically, the difference in gastropods in the mangrove ecosystem of the north coast of Jakarta was influenced by seawater supply, freshwater supply, and the potential and frequency of water inundation (Belhiouani et al. 2019; Susintowati et al. 2019; Hilmi et al. 2021c. 2022b). Meanwhile, the potential for pH and salinity in mangrove ecosystems has relatively the same score. Therefore, permanent waterlogging is a triggering factor for environmental changes that require adaptation patterns for surviving gastropods.

Table 5. The distribution index of gastropods in north coast of Jakarta, Indonesia

Species	Morosita index (Id)						Score	Distribution pattern
	Station							
	1	2	3	4	5	6		
Cassidula angulifera	0	0	0	0	0	0.01	0.01	Uniform
Cassidula aurisfelis	0	0	0.04	0	0	0	0.04	Uniform
Cassidula plecotrematoides	0	0	0	0	0	0.01	0.01	Uniform
Cassidula rugata	0	0	0.01	0	0	0	0.01	Uniform
Cerithidea obtusa	0	0	0	0	0.01	0	0.01	Uniform
Cerithidea quoyii	0	0	0	0	0	0	0	Uniform
Ellobium aurisjudae	0	0	0	0	0	0	0	Uniform
Ellobium gangeticum	0	0	0	0	0	0	0	Uniform
Melanoides tuberculata	0	0.02	0	0	0	0	0.02	Uniform
Nassarius reticulatus	0	0	0	0.04	0	0	0.04	Uniform
Neritina violacea	0	0	0.01	0	0	0	0.01	Uniform
Pila ampullacea	0.14	0.01	0	0	0	0.06	0.21	Uniform
Pythia plicata	0	0	0	0.01	0	0	0.01	Uniform
Total	0.18	0.08	0.17	0.21	0.04	0.19	0.87	Uniform

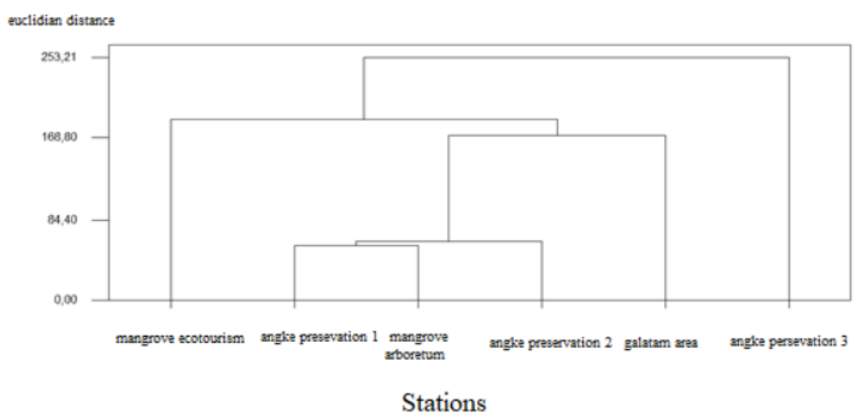

Figure 5. Clustering of gastropod's habitat

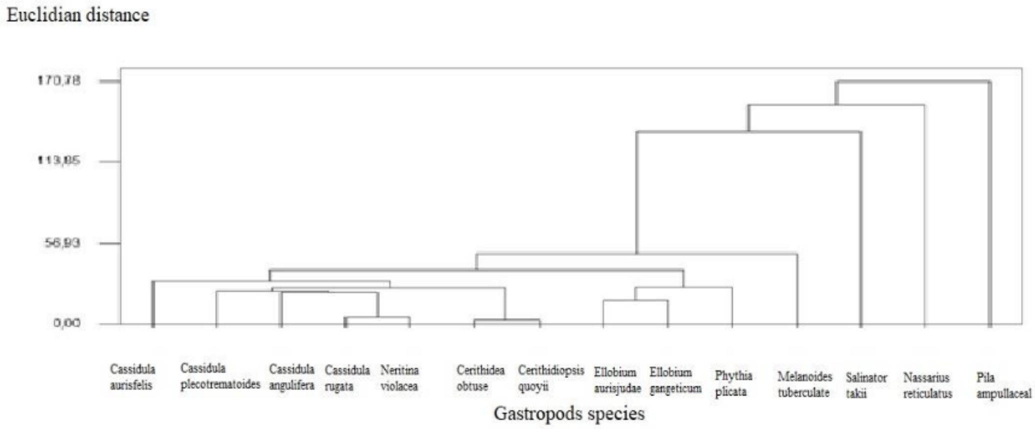

Figure 6. Clustering of gastropods species

Clustering of gastropods species

The clustering of gastropod species in the mangrove ecosystem of the north coast of Jakarta could be seen in Figure 6. The clusters of gastropods species on the north coast of Jakarta showed that *C. obtusa-Cerithidea quoyii* and *C. rugata-N. violacea*, have a very high affinity. Then *E. aurisjudae, E. gangeticum, and P. plicata* have a fairly high affinity. The gastropod species *C. angulifera, C. aurisfelis, C. plecotrematoides, C. rugata, C. obtusa, Cerithidea quoyii,* and *N. violacea* have a moderate affinity. Meanwhile, *Salinator takii, N. reticulatus,* and *Pila ampullacea* aren't affinity or less affinity.

The cluster pattern of gastropods species had a high relationship with the permanent inundation of brackish water (Belhiouani et al. 2019; Hilmi et al. 2019. 2021a; Susintowati et al. 2019; Andriyani et al. 2020; Rahman et al. 2021). Basically, gastropods abundance is influenced by lifestyle in permanent water inundation, which affects the water column, and food, through ingestion of inorganic particulate matter and mangrove litter (Teoh et al. 2018; Belhiouani et al. 2019; Bhandari et al. 2021; Nurhayati et al. 2021; Rahman et al. 2021). This condition will affect gastropods' distribution and adaptation patterns (Peng et al. 2017; Reis et al. 2021). The cluster pattern also follows the feeding and life activity in the low tide ground or climbing the trees (Lazzeri et al. 2014; Lazzeri 2017). This activity also had relationships with the potential of organic matter consumption, dynamics of suspended material, and sedimentation (Lazzeri et al. 2014; Lazzeri 2017).

The clustering and relationships among gastropod species are also influenced by the composition and configuration of mangrove species as an important factor in supporting the activity, behavior, growth, survival, occurrence, and distribution of many gastropods (Bhandari et al. 2021; Cacabelos et al. 2021). Habitat preferences also influence the clustering of gastropods species, biotic and abiotic interactions, the activity of gastropods, pattern and duration of inundation, water salinity, pH, and water uses (Bhandari et al. 2021; Cacabelos et al. 2021). And the clustering of gastropod species also impacts the association, relationships, and affinity of gastropods (Bathmann et al. 2021; Bhandari et al. 2021; Cacabelos et al. 2021).

In conclusion, the permanent water inundation in the mangrove ecosystem north coast of Jakarta greatly impacts the affinity of Gastropods, both association, and clustering of gastropods. The mangrove ecosystem on the north coast of Jakarta is dominated by *C. angulifera, C. aurisfelis, C. plecotrematoides, C. rugata, E. aurisjudae, E. gangeticum, P. plicata, C. obtusa, C. quoyii,* and *M.sarius tuberculata* with abundance between 0.36 to 6.68 ind/m2. The gastropods have 12 pairs of positive associations from 78 pairs, uniform distribution, and two clusters.

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