Relationship between gastropods (*Cassidula nucleus* and *Cassidula vespertilionis*) and mangroves (*Avicennia marina* and *Sonneratia alba*) in a rehabilitated mangrove ecosystem in Pantai Indah Kapuk, Jakarta, Indonesia

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Abstract. The mangrove forest of Pantai Indah Kapuk, Jakarta results from the rehabilitation of a previously damaged ecosystem due to land conversion into fishponds. Gastropods such as *Cassidula nucleus* and *Cassidula vespertilionis* in the area have a high tolerance to the environment, i.e. the ability to survive in a polluted environment. The present study, performed in November 2019, examined the relation between gastropods (*C. nucelues* and *C. vespertilionis*) and mangroves (*Avicennia marina* and *Sonneratia alba*) in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk Jakarta. The sampling of gastropods, substrates, and environmental characteristics used a purposive sampling method. The relation between gastropods and mangroves was analysed by regression. The variation of the environmental characteristics among research substations was analysed using the Principal Component Analysis (PCA). The research results showed that the highest abundance of gastropods is found in *A. marina* mangrove with *C. nucleus* (60 individuals 100 m^{-2}) and *C. vespertilionis* (80 individuals 100 m^{-2}). *C. nucleus* and *C. vespertilionis* have a positive correlation with mangrove density with (r) values of 0.75947 and 0.90255, respectively.

Key Words: Angke River, Ellobidae, indicator, sediment, TOM.

Introduction. The mangrove ecosystem of Pantai Indah Kapuk, Jakarta, in Jakarta Bay, North Jakarta, is the result of mangrove rehabilitation. Previously, the area was damaged due to land conversion into fishponds. The mangrove species which grow in the area are *Avicennia marina* and *Sonneratia alba*. The population of each species has a different density. According to Kusdharwito (2015), the density of the mangrove ecosystem of Pantai Indah Kapuk, Jakarta, ranges between 1,000 and 1,500 individuals ha^{-1}, with a mangrove canopy height of 700 meters.

Mapoko et al (2017) found that the density of gastropods is correlated with mangrove density, which is also supported by Silaen et al (2013), Nurfitriani et al (2019), Crisnawati et al (2017), who stated that the presence and abundance of gastropods are affected by mangrove density and environmental characteristics. The rehabilitated mangrove ecosystem of Pantai Indah Kapuk Jakarta receives environmental pressures from the anthropogenic activities along the River Angke (Putri et al 2015). These activities are suspected to affect the environmental characteristics and the density of mangrove populations. Kurniawati et al (2014) stated that a high density produces more litter, which becomes a food source for gastropods. Silaen et al (2013) also observed that abundance and distribution of gastropods are affected by environment, food, and predator.

Cassidula nucleus and *Cassidula vespertilionis* (Ellobidae) have a higher tolerance to their environment, i.e. they are able to survive in a polluted environment and are alleged to be good environmental pollution bioindicators (Kantharajan et al 2017).

Therefore, information on the abundance of gastropods in the mangrove ecosystem is necessary. The present paper aimed to study the relation between the abundance of *C. nucleus* and *C. vespertilionis* and *A. marina* and *S. alba* mangrove in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta.

Material and Method

Description of the study sites. The research was undertaken in November 2019 in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta. The research site was determined using a purposive sampling technique, i.e. based on the mangrove population (*A. marina* and *S. alba* population). Site data collection was performed on both the mangrove populations, i.e., *A. marina* and *S. alba* population, with three iterations (Figure 1). *A. marina* population is located near the estuary flow (substations 1.1, 1.2, and 1.3) while *S. alba* population is situated near the sea and not too far from the estuary flow (substations 2.1, 2.2, and 2.3).

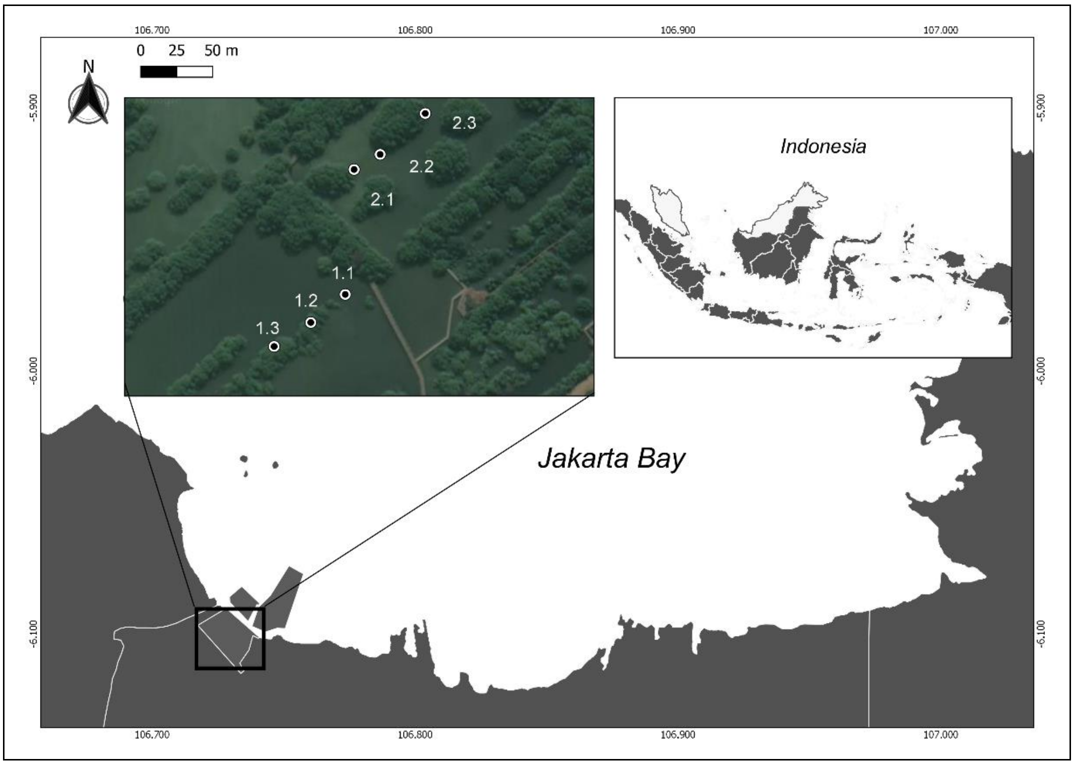


Figure 1. Substation of the relation between gastropods (*Cassidula nucleus* and *Cassidula vespertilionis*) and mangrove (*Avicennia marina* and *Sonneratia alba*) in rehabilitated mangrove ecosystem in Pantai Indah Kapuk, Jakarta.

Data collection. The sampling method for gastropods was based on Mappoko et al (2017), i.e. using 5 x 5 m transect and three iterations in each research station. Gastropod sampling was performed during low tide by hand (hand picking). Gastropods were collected along a 1 x 1 m transect (on mangrove substrates, roots, or leaves). Gastropod samples were preserved by being submerged in 4% formalin for 2 hours, then stabilized in 70% ethanol.

The mangrove vegetation sampling used 100 m^2 transect (10 x 10 m) by tree category. The number of individuals and the diameter of the mangrove trunk was recorded by tree category (diameter >4 cm) (Kitamura et al 1997). Tree diameter measurement was performed by Cintron & Novelli (1984).

Sediment sampling was performed at a depth of 10 cm from the substrate surface in each plot of the six substations. Sediment samples were collected using sediment corer with 5 cm diameter and 1 m length (Round 1971; English et al 1994). Then, the sediment fraction and redox potential (Eh) were measured using a pipette and Eh meter.

Meanwhile, Total Organic Matter (TOM) was determined using ash content measurement. The pH, temperature, salinity, and dissolved oxygen (DO) were measured in situ.

Data analysis. The composition of gastropod types was identified based on literature review: Abbott & Dance (1982), Dharma (1988), Habe (1975), and Dharma (2005). The abundance of gastropods in every research sub-station was measured by the following formula of Chusna et al (2017):

$$N = \frac{\Sigma ni}{A}$$

Where:
N- abundance (individual m^{-2});
Σ_{ni}- the number of individuals of the i^{th} type;
A- the size of the plot where the i^{th} type is found.
The composition of mangrove types in each substation was identified using the book of Kitamura et al (1997). Type density (K) was the number of individuals per unit area (in individuals ha^{-1}), calculated with the formula (Bengen 2004):

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

Where:
K_i- the density of species i;
n_i- total i^{th} individual;
A- the total sampling area (m^2).
The relation between gastropods and mangroves was analyzed using the linear regression. The variation of the environmental characteristics by station was analyzed using the Principal Component Analysis (PCA) (Bengen 2000).

Results. Table 1 shows the density and DBH (diameter at breast height) of mangrove by sub-station and mangrove population in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta. The present study showed that the highest mangrove density was found at the sub-station 1.1 in the *A. marina* population (23 individuals 100 m^{-2}), while the lowest density was found at the sub-station 2.2, in the *S. alba* population (1 individual 100 m^{-2}).

Table 1

Density and DBH of mangrove by sub-station and mangrove population in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta

Mangrove population	*Substations*	*Density (individual 100 m^{-2})*	*DBH (cm)*
Avicennia marina	1.1	23	12.36±5.09
	1.2	10	14.46±3.67
	1.3	11	17.68±8.57
Sonneratia alba	2.1	7	21.25±11.60
	2.2	1	24.62±0.00
	2.3	2	27.88±30.06

DBH-diameter at breast height.

The abundance of C. nucleus and C. vespertilionis. The abundance of *C. nucleus* and *C. vespertilionis* in the patches occupied by *A. marina* and *S. alba*, in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta, is displayed in Figure 2. The highest abundance of gastropods was observed in *C. nucleus* (60 individuals 100 m^{-2}) and in *C. vespertilionis* (80 individuals 100 m^{-2}) at the sub-station 1.1, populated with *A.*

marina. Meanwhile, substations 2.2 and 2.3 with *S. alba* population did not produce any gastropod.

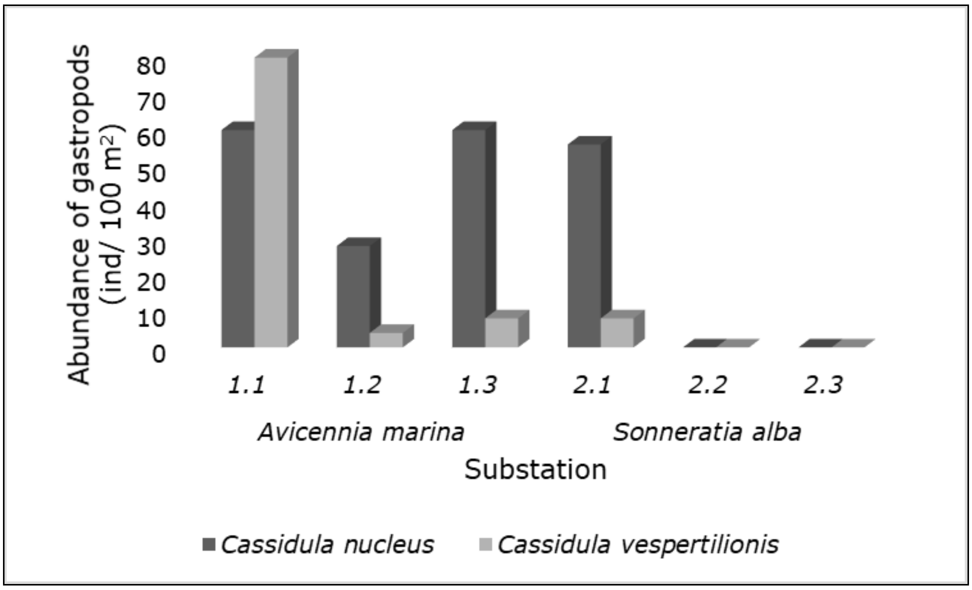


Figure 2. The abundance of *Cassidula nucleus* and Cassidula *vespertilionis* in mangrove populations of *Avicenna marina* and *Sonneratia alba.*

Variation of environmental characteristics. The environmental characteristics at each sub-station have variable values. The value of DO of the waters ranged from 5.90 to 8.77 mg L^{-1}, the temperature value of the water ranged from 27.33 to 29.67°C, the salinity value of the water ranged from 24.67 to 27.00 ppt, and the pH value of the water range from 6.66 to 6.86. Table 2 shows that substation 2.3 has the highest TOM value (73.27%) and the lowest Eh value (28.00 mv), with the texture class of a silty clay substrate. Substation 1.3 had the lowest TOM (52.47%), for an Eh value of 30.00 mv, with the texture class of a clay substrate.

Table 2

Environmental characteristics by substations in a rehabilitated mangrove ecosystem in Pantai Indah Kapuk, Jakarta

Substations	*TOM (%)*	*Eh (mv)*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Texture class*
1.1	54.77	31.00	14.24	43.24	42.23	Ldb
1.2	70.20	28.00	10.72	50.86	38.41	LeLdb
1.3	52.47	30.00	12.98	36.83	50.20	L
2.1	67.21	31.00	25.69	46.63	27.69	Leli
2.2	67.87	35.00	21.45	55.40	23.15	Ledb
2.3	73.27	28.00	22.13	54.82	23.05	Ledb

TOM-Total Organic Matter; Eh-Redox potential; L-Clay; Ldb-Silty clay; LeLdb-Silty clay loam; Leli-Clay loam; Ledb-Silty loam.

The relation between the sub-station and the environmental characteristics can be viewed in Figure 3. PCA results show a total variance (F1 and F2) of 89.27%, with the F1 variance of 64.74% and the F2 variance of 24.53. Figure 3 shows that substations 1.1 and 1.3 were characterized by clay substrate, substations 2.1 and 2.2 were characterized by Eh and sand substrate, while TOM and silt characterized substation 2.3. Variables with opposing arrow had a negative relation, while variables close to each other and with the same direction had a positive relation.

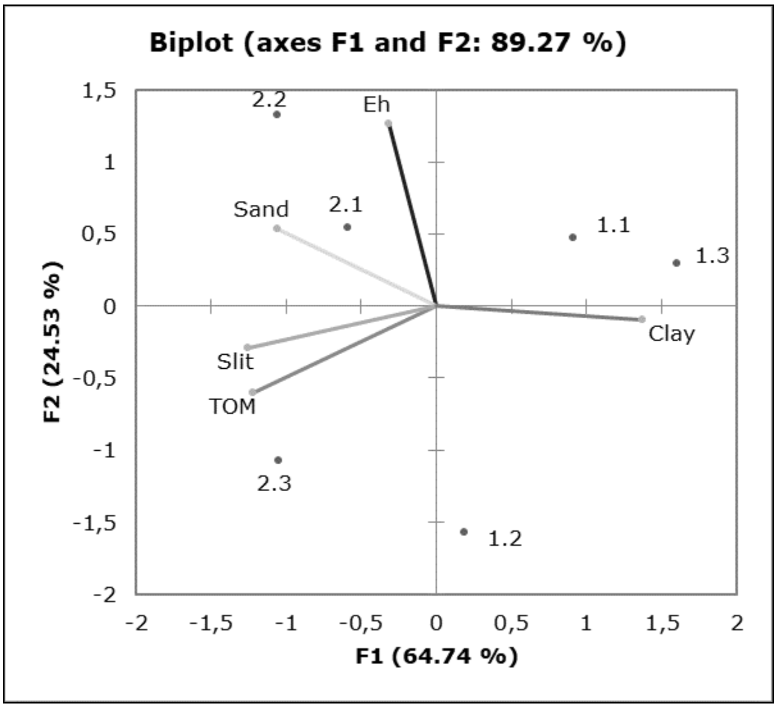
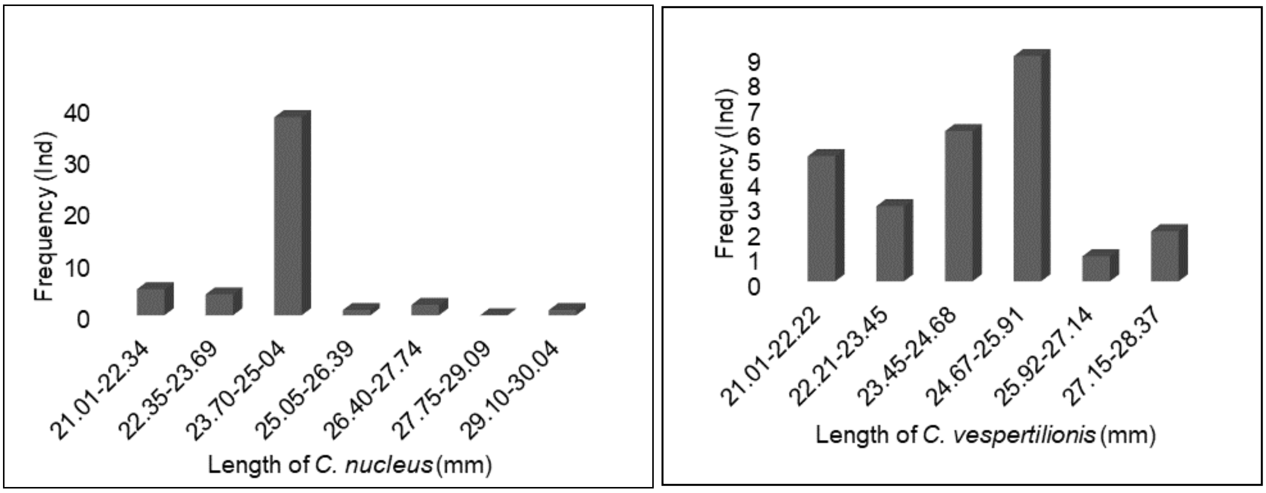


Figure 3. Principal component analysis (PCA) of environmental characteristics in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta.

The relation between gastropods and mangroves. The characteristics of the distribution of the length C. *nucleus* and C. *vespertilionis* in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta were displayed in Figure 4.



A B

Figure 4. The class distribution of the lengths of gastropods A (*Cassidula nucleus*); B (*Cassidula vespertilionis*) in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta.

C. nucleus had an average length of 21.00-30.04 mm, while *C. vespertilionis* had an average length of 21.01-28.37 mm. The highest *C. nucleus* distribution was for the length of 23.70-25.04 mm (40 individuals), while the highest *C. vespertilionis* distribution was for length of 24.67-25.91 mm (9 individuals). Figure 4 shows that the number of *C. nucleus* was higher than *C. vespertilionis.*

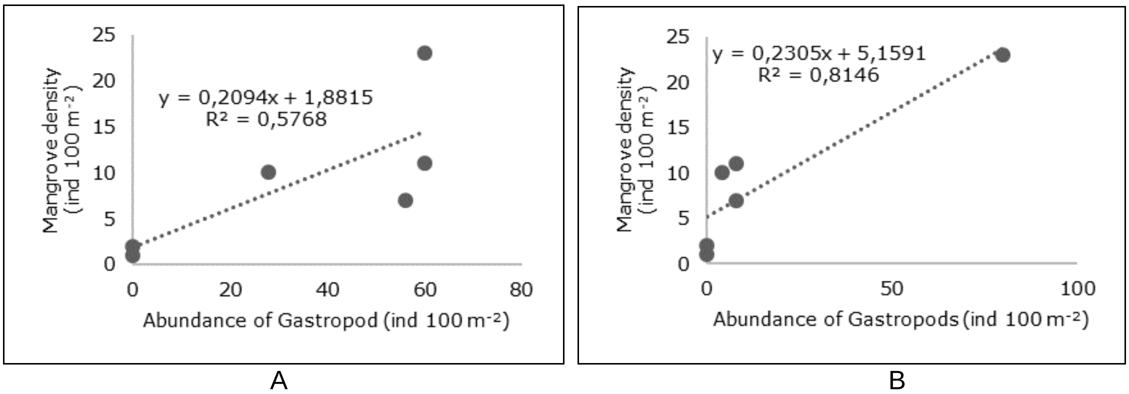


Figure 5. Regression of mangrove density and abundance of *Cassidula nucleus* (A); *Cassidula vesvertilonis* (B) in the rehabilitated mangrove ecosystem of Pantai Indah Kapuk, Jakarta.

Regression of mangrove density and abundance of *C. nucleus* and *C. vespertilionis* can be seen in Figure 5. Figure 5 shows the determination coefficient value R^2 of *C. nucleus*, and mangrove density is 0.5768 with (r)=0.75947. The value of determinant coefficient R^2 of *C. vespertilionis* and mangrove density is 0.8146 with (r)=0.90255. It shows that the correlation of mangrove density with *C. nucleus* and *C. vespertilionis* was positive.

Discussion. According to the reference values established by the MNLH (2004), the density of *A. marina* at substation 1.1 was high (≥15 individuals 100 m^{-2} or ≥1500 individuals ha^{-1}) and the density of *S. alba* in all of the substations was low (<10 individuals 100 m^{-2} or <1000 individuals ha^{-1}). The high density of *A. marina* in substation 1.1 (Table 1) was affected by its adaptability, and regeneration capacity, when supported by a suitable habitat (Hartoni & Agussalim 2013; Do et al 2019). Moreover, the number of individuals and the DBH of mangrove trees affected their density value. According to Bengen (2004), mangrove density was produced by the number of individuals per area size. Based on the result, the more individuals are in an area, the smaller the average DBH of mangrove. This relationship is in line with the observations of Idrus et al (2014), concluding that *S. alba* has greater DBH and height than *A. marina.*

The research result showed that substation 1.1 in *A. marina* population had the highest salinity (27.00 ppt). Jahid & Singh (2018) stated that *A. marina* can adapt to a high salinity and this was confirmed by Halidah & Kama's (2013) study in Tiwoho Village, North Minahasa Regency, North Sulawesi. *A. marina* can grow well in 30 ppt salinity. Hastuti et al. (2012) argue that *A. marina* and salinity have a positive correlation, i.e., the higher the salinity, the higher the ability of *A. marina* to grow.

The research result indicated that *C. nucleus* and *C. vespertilionis* were affected by the substrate, being found only at substations 1.1, 1.2, 1.3, and 2.1, in a dry substrate, while the other substations 2.2 and 2.3 had a submerged substrate. According to Chusna et al (2017), *C. nucleus* and *C. vespertilionis* live on a dry substrate surface and climb on a tree trunk, leaf and root. Moreover, gastropods were also affected by the mangrove density and by the substrate texture class. Substations 1.1 and 1.3 had the highest mangrove density and abundance of gastropods (Table 1 and Figure 2). Prasanna et al (2017) stated that high mangrove density produces a higher litter, so there is a more organic material for gastropods. The research result showed that the substation with the highest abundance of gastropods (substations 1.1 and 1.3) is characterized by silty clay and clay substrate texture classes (Figure 3). According to Chusna et al (2017), the clay substrate has a positive correlation with the abundance of gastropods.

According to KLH No 201 (2004), gastropods can live in DO>5 mg L^{-1}. It proves that all research substations have normal DO for *C. nucleus* and *C. vespertilionis.* The research result showed that *C. vespertilionis* was more commonly found in low DO (7.10 mg L^{-1}), and it was consistent with the statement of Crisnawati et al (2017). Satheeshkumar & Khan (2012) also stated that *C. vespertilionis* is more commonly found in 7.7-8.0 mg L^{-1} DO.

The research result showed that *C. nucleus* was found 25.00-27.00 ppt salinity, presumably being more affected by the salinity. According to Dissanayake & Chandrasekara (2014), *C. nucleus* and *C. vespertilionis* prefer lower salinity, probably because gastropods can withdraw into their shells when in danger. These observations are supported by the study of Rumhalatu & Leiwakabessy (2017) related to the mangrove ecosystem of Ambon Island, where there no *C. nucleus* was found in 30.09-30.35 salinity. The salinity difference explains the presence or absence of *C. nucleus*.

Substation 1.2 had 8.70 mgL^{-1} DO and was characterized by silty clay loam substrate, with higher percentages of silt and clay than sand. According to Kurniawati et al (2014), the DO value is affected by a fine substrate. TOM values in all research substations were 52.47-73.27%, respectively, which was consistent with the study of Kurniawati et al (2014) in Segara Anakan mangrove ecosystem of Cilacap Regency, Central Java, which showed a TOM percentage of 57.47-72.70%. *S. alba* population in the research location had an average salinity of 26 ppt with mud substrate. This result was consistent with the study of Yolanda et al (2016) in the mangrove ecosystem of Padang Island, where *S. alba* population was found in asalinity of 26 ppt, in mud substrate.

The regression of mangrove density and gastropods abundance in Figures 5 (A) and (B) shows (r) approaching +1, showing that the relation among variables is strong. The distribution of *C. nucleus* and *C. vespertilionis* was affected by species population and mangrove density, which was consistent with the statements of Islami (2015) and Ariyanto et al (2018), namely that abundance of gastropods, is positively correlated with mangrove density. High mangrove density produces more litter, which is decomposed by microorganisms, and indirectly affects the presence and distribution of gastropods. The effects of the mangrove density on the abundance of *C. nucleus* and *C. vespertilionis* are of 57.68 % and 81.46 %, respectively. Meanwhile, 42.32% and 18.54% are affected by other factors.

Imakulata & Tokan (2018) stated that gastropods live in mangrove ecosystems and play a role in their ecology, i.e. supporting food network in the ecosystem. Silaen et al (2013) stated that *C. nucleus* is more commonly found in the denser mangrove ecosystem. The current research is consistent with the latter observation: *C. nucleus* was found in *A. marina*, while *S. alba* had less density than *A. marina*, which determined the gastropod absence at substations 2.2 and 2.3.

Conclusions. The rehabilitated mangrove ecosystem in Pantai Indah Kapuk Jakarta has *A. marina* and *S. alba* populations, supporting the abundance of *C. nucleus* and *C. vespertilionis.* The research results showed that the abundance of gastropods in *A. marina* was higher than in *S. alba*, with *C. nucleus* predominating. *C. nucleus* and *C. vespertilionis* were positively correlated with mangrove density, i.e. a high mangrove density was followed by an abundance of gastropods.

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