Distribution Patterns And Species Density of *Pirenella cingulata* (Gmelin, 1971) In The Mangrove Forest Of Pangpang Bay, Ijen Geopark Banyuwangi Indonesia

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Abstract

Mangrove Forest Pangpang Bay is the result of a 1999 restoration work and has been classified as an Essential Economic Zone (KEE) due to its diversified area and flora and fauna. The mangrove forest of Pangpang Bay is home to Pirenella cingulata, a macro-invertebrate that is found in muddy mangrove substrates. Pirenella cingulata is a detritivore that feeds on rotting litter. This study looked at the distribution and population density of P. cingulata in the mangrove forest of Pangpang Bay, Banyuwangi. Data was collected using a 1x1 m² transect plot with diagonal placement. Data analysis for distribution patterns using the morisita index and population density was analyzed using the formula number of individuals divided by the area. Temperature, salinity, pH, and substrate type are some of the environmental characteristics observed and interpreted as supporting evidence for distribution patterns. There were 824 individuals of the P. cingulata species discovered from 120 plots in Pangpang Bay and it has a concentrated distribution. The population density was of 6.86 individuals/m², or seven individuals per 1 m². This density figure suggests a high category in Pangpang Bay. The findings of this study can be used to create management plans for the conservation of gastropods *P. cingulata* in the mangrove forest of Pangpang Bay

Keywords: Distribution patterns, *Pirenella cingulata*, mangrove forest, pangpang bay

INTRODUCTION

Mangrove forest in Pangpang Bay is a wetland ecosystem located in Banyuwangi Regency between Muncar and Tegaldlimo with an area of 425 ha (Rodiana *et al.,* 2019; Ariyanto *et al.*, 2020a). The area resulted from a reforestation programme in 1999 and was designated as an Essential Ecosystem Area (KEE) because of its large area and diverse flora and fauna (Pradana *et al.,* 2023). One of the macro-invertebrates commonly found in mangrove forest Pangpang Bay is a member of the Gastropoda class or known as mangrove snails because there is a mud substrate that supports their life (Susanti *et al.,* 2021; Tuheteru *et al.,* 2014). According to Dharma (2005), one of the families of the Gastropoda class found in mud substrates is the Potamididae family. One of the species of the Potamididae family found in the mangrove forest of Pangpang Bay is *Pirenella cingulata* (Susanti *et al.,* 2021).

The species *P. cingulata* has the characteristics of a conical shell with a convex whorl body then cones to the apex so that it looks tapered (Arbi *et al.,* 2013; Slamet *et al.,* 2021). In general, *P. cingulata* populations can live in intertidal areas, sandy coasts and mangrove forests with mud substrate types (Arbi *et al.,* 2022). The distribution of *P. cingulata* can be found in mangrove areas around the world that have mud substrates (Setiawan *et al.,* 2021). The habitat of *P. cingulata* in mangrove forest areas is found on the surface of the substrate (epifauna), under the shade and when the tide will attach to mangrove roots (Arbi *et al.,* 2022). Arbi (2013) states that the presence of *P. cingulata* serves an ecological role as a detritivor in the food chain in mangrove forests. *Pirenella cingulata* utilises decaying litter because it is thought to contain microalgae or fungi as its food source. The ecological role of *Pirenella cingulata* in the mangrove forest Pangpang Bay is as mangrove leaf litter detritus and is a food source for other organisms such as crabs and seabirds.

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The distribution pattern refers to the arrangement of individuals within their habitat. As stated by Kim and Kong (2020), there are three types of distribution patterns: even, random, and clustered. It is rare for organisms in nature to be randomly distributed. Each individual can be found in certain locations and not in others. According to Krebs (2001), distribution pattern of species can be influenced by various factors, such as habitat preference, environmental conditions, competition, and predator presence. In the mangrove forest of Pangpang Bay, *P. cingulata* was found in muds, mangrove roots, and behind the leaf litter areas (Setiawan *et al.,* 2021). Research on distribution patterns is important to understand the distribution of this species within the ecosystem, as it is not found in other mangrove ecosystems within the Alas Purwo National Park area. Therefore, research on the distribution patterns of *Pirenella cingulata* will provide information on the distribution of this species within the mangrove ecosystem and add to the database on the presence and population of this species for Alas Purwo National Park.

Reforestation that have been carried out are expected to cause changes in a habitat in the mangrove forest Pangpang Bay. These activities will change the condition of an environment that will have an impact on changes in the habitat of an organism, such as the availability of food sources for an organism. The availability of food sources is a factor in the spread of species because organisms tend to choose areas where there are abundant food sources and favourable environmental conditions for their growth (Muro-Torres *et al.,* 2020). Knowledge of the population of *P. cingulata* is needed to maintain the sustainability of mangrove forest management in Pangpang Bay. Local people do not consume this type because of its small size and it is not as popular as other types of gastropods such as telescopium and shellfish. This study investigates the distribution pattern and population density of *P. cingulata* in mangrove forest area Pangpang Bay, Banyuwangi. The findings can also be used to increase public awareness about the sustainability of the mangrove forest Pangpang Bay ecotourism area and the development of future conservation strategies for this species.

MATERIAL AND METHODS

This research was conducted in February - April 2023 in the Mangrove Forest Pangpang Bay of Banyuwangi Regency with an area of approximately ± 20.8 hectares. The geographical location of mangrove forest Pangpang Bay is between 8º27'0,000‘’- 8º27'36,000‘’South latitude and 114º21'0,00‘’- 114º21'36,000‘’East longitude (Figure 1). Identification of this species based on the shape, size, color and pattern of the shell (Carpenter & Niem, 1998; Dharma, 2005).

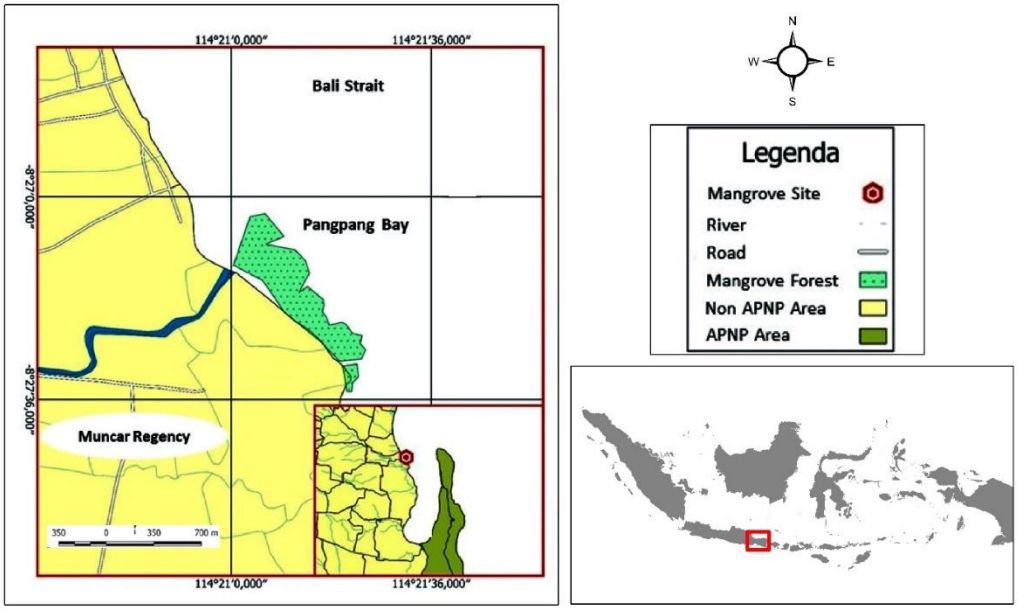

Figure 1. Map of Sampling Location at Mangrove Forest, Pangpang Bay Ijen Geopark

Sampling *P. cingulata* used transect-plots with a size of 1 x 1 m² that were laid out systematically (Figure 2). This data collection was conducted within a large plot with a plot size of 10 x 10 m². The large plot was used as the basis for laying 1 x 1 m² plots diagonally to make it easier to determine the upper, middle and lower points in data collection (Setiawan *et al.,* 2024). Collecting *P. cingulata* was carried out during low tide conditions, to be easy to collect and observe the number of individuals. The initial stage of collecting *P. cingulata* by laying a 10 x 10 m² plot as the basis for laying 1 x 1 m² plots diagonally (Figure 3). The distance between plots is 2.5 m and the distance between 10 x 10 m² plots is 20 m (Setiawan *et al.,* 2024). The boundaries of the research area in the mangrove forest of Pangpang Bay were determined using a Garmin 64S GPS. The length of the research area is approximately 1600 metres with a total of approximately 120 plots laid.

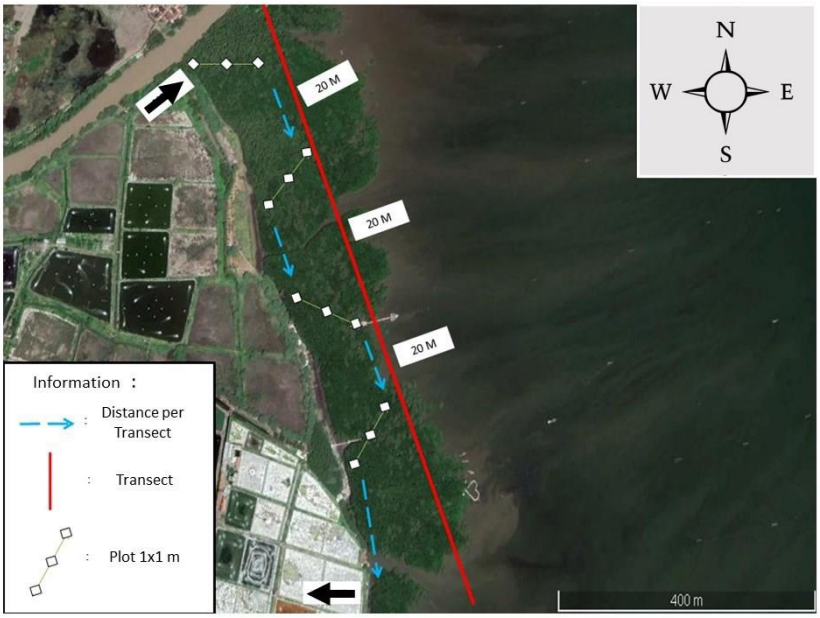

Figure 2. Techniques Collecting Based on Mangrove Forest Pangpang Bay

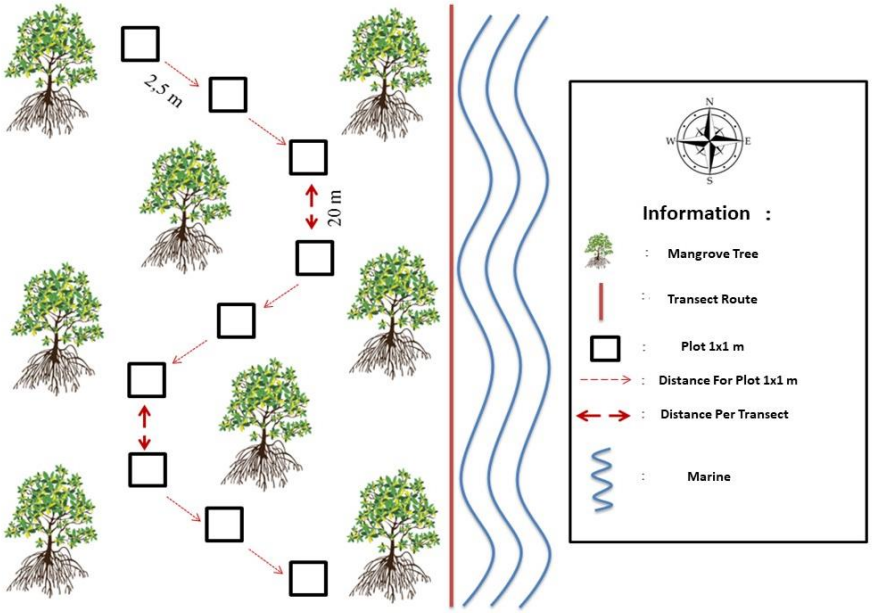

Figure 3. Technique of Schematic data collection in the Mangrove Forest Pangpang Bay

Thorough observations were made in each 1x1 m² plot to determine the species of *P. cingulata* to be counted. Specimens can be found on the surface of the substrate at low tide (epifauna) and at high tide attached to the roots of mangrove trees. Specimens of *P. cingulata* that were found then placed into a tray for counting. *Pirenella cingulata* representatives were taken as many as 20 individuals at random and then put into ziplock plastic for further identification. Specimens then cleaned using a brush and rinsed using water to clean the mud attached from shell. The specimen was then placed on millimetre paper and documented using a DSLR camera. Documentation was carried out on the ventral and dorsal parts of the specimen. Morphometric measurements were carried out to determine body size including shell length and width using a bar scale. Abiotic data measurements include water pH, water temperature, salinity and substrate type which are measured when sea water conditions are low tide. Abiotic data collection was carried out by looking for puddles in the 1 x 1 m² plot area or around the 10 x 10 m² plot. Measurements were taken in 12 predetermined plots and measured three times.

The distribution pattern of *P. cingulata* can be calculated using the Morisita distribution index. Morisita index (Iδ) is one of the indices that can determine the distribution pattern of a species. According to Krebs (2001), distribution patterns can be calculated and determined using the Morisita index with the following equation:

$$I\delta = n\left[\frac{\sum X^2 - \sum X}{(\sum X)^2 - \sum X}\right]$$

The morisita distribution index (Iδ) is the product of the total number of plots (n) by dividing the total number of *P. cingulata* individuals in each plot (∑X) by the total square of the number of *P. cingulata* individuals in each plot $(\sum X)^2$. This index calculation is done manually using MS Excel. According to Krebs (2001), the Morisita index value is used to determine the distribution pattern using the criteria of Iδ = 1 which means a random distribution pattern, Iδ < 1 which means a uniform distribution pattern, and Iδ > 1 which means a clustered distribution pattern. The next data analysis was to determine the density value of *P. cingulata* species. The species density value (Di) is the number of individuals of a species (ni) divided by the total area of the research plot (m²) (N) (Krebs, 2001).

RESULT AND DISCUSSION

The total number of individuals of *P. cingulata* found in the mangrove forest area Pangpang Bay is 824 individuals from a total of 120 plots. The data were then analysed using the Morisita index. The calculation results obtained a value of 6.19 which means that the type of distribution pattern of *P. cingulata* is clustered. *Pirenella cingulata* found in Pangpang Bay has a shell length between 1 - 6 cm with a shell width between 0.2 – 1.5 cm (Figure 5). *Pirenella cingulata* is a member of the soft-bodied Gastropod class protected by a shell. Shape of the shell of *P. cingulata* is conical and the sides of the shell are convex (Figure 4). Shell type of *P. cingulata* is turreted and composed of calcium carbonate, the outside of which is coated with periostrakum and horn substance. Shell colour is dark brown and on the whorl there are white dots. This shell has a rotation direction to the right or clockwise (dextral). Tip of the shell is called the apex which is tapered. The aperture is oval with a narrowed tip forming an angle. *Pirenella cingulata* has a multispiral-type operculum with a nucleus in the centre and is chitin-based.

The distribution pattern of *P. cingulata* is clustered due to influencing factors including habitat, food availability, reproductive behaviour and abiotic environmental factors. The presence of *P. cingulata* is found in large numbers in the mud substrate area because this area contains a lot of organic matter as a food source. In addition, the mud substrate is also a refuge from predators. The habitat of this species is mostly found in the surface area of the substrate (epifauna) which is inundated by water around mangrove plants of *Rhizopora* spp. *Rhizopora* spp. mangrove species have roots that extend into the substrate towards the soil surface and form small crevices (Ohtaki *et al.*, 2016; Sari *et al.*, 2017).

The condition of the *Rhizopora* spp. roots is an important habitat for *P. cingulata* because in addition providing litter to be as a food source, the root gaps can also be used as a shelter. This condition was thought to affect the distribution pattern because this species chooses areas with mud substrates that support its life and shelter from utilising mangrove roots as a refuge from predators to form a group. This is also supported by the statement of Reid *et al.* (2013) that litter produced from mangrove trees has organic matter content to be used as a food source for *P. cingulata* and can increase water productivity water productivity so

that it can cause organisms to clustered. Vannini *et al.* (2006) states that *P. cingulata* are found in *Rhizophora* spp. mangrove ecosystems because they can provide mud substrates which are the habitat of *P. cingulata*.

This species has a clustered distribution pattern, which means that it occupies its preferred habitat, namely litter piles of relatively similar age and size. Another factor influencing the clustered distribution pattern is food availability. Based on observations, *P. cingulata* was found in large numbers and clustered in mud substrate areas and around mangrove vegetation litter. Mangrove vegetation litter was found in the study area but scattered in certain areas due to tidal activity. Pangpang Bay has a unique and strategic location because it is located in a dense mangrove forest area and is dominated by homogeneous mangrove vegetation at the research site. *Ceriops tagal* dominates the mangrove forest in Pangpang Bay with smaller leaves and is thought to be favored by *Pirenella cingulata*. *Pirenella cingulata* utilise decomposed mangrove litter because it is thought to contain microorganisms such as microalgae and fungi as a food source. This is thought to cause this animal to cluster in certain areas because it chooses areas with abundant food sources. According to Persulessy and Arini (2018), the ecological role of *P. cingulata* in the food chain in mangrove forests as detritus eaters or called detritivores by utilising

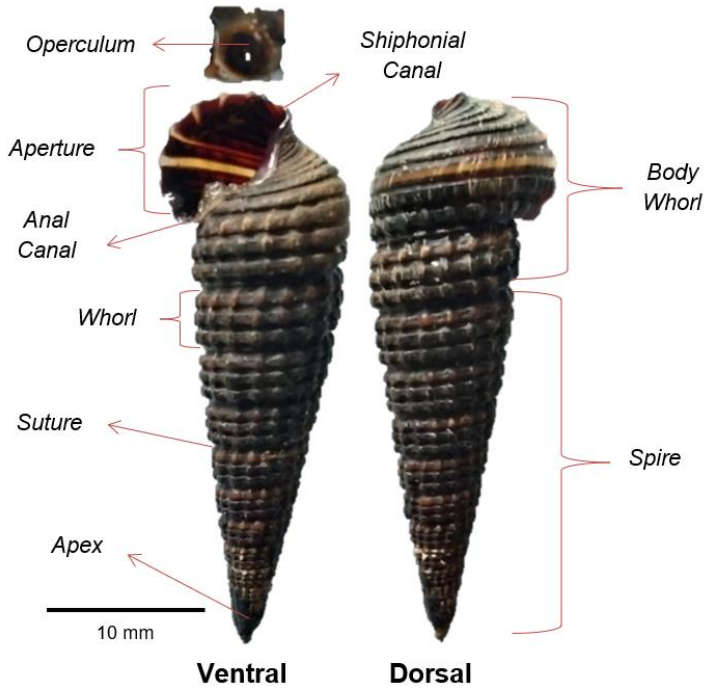

Figure 4. Shell Morphology of *Pirenella cingulata* in Mangrove Forest Pangpang Bay

Figure 5. Shell Size Variation of *Pirenella cingulata* in Mangrove Forest Pangpang Bay

decaying litter as a food source. This is also supported by the statement of Sari *et al.* (2017), that a population tends to cluster due to the presence of mud substrates that support its survival and litter that has decayed into a good habitat for microorganisms such as fungi and microalgae as a food source for *P. cingulata*. Many *P. cingulata* populations are found clustered in areas that provide organic matter as a food source for the species.

Another factor that influences clustered distribution patterns is reproductive behaviour (Krebs, 2001). Reproductive behaviour can occur if habitat conditions and environmental conditions are favourable. Based on observations, *P. cingulata* species were found with various sizes and live in groups. It is suspected that the *P. cingulata* brood releases eggs during the reproduction process and then develops into new individuals to form a colony. Ohtaki *et al.* (2016) states that Gastropods are hermaphroditic animals but cannot fertilise themselves (autofertilisation) so that spermatozoa from other individuals are needed. The reproductive process of *P. cingulata* occurs by copulation through internal fertilisation (Thao *et al.,* 2018). The results of research by Thao *et al.* (2018) showed that members of the genus *Pirenella* can produce many eggs in a fairly short time. *Pirenella cingulata* hatches its eggs within seven days after the incubation period. The results of this statement suggest that the grouping activity of these animals is related to the reproductive behaviour of *P. cingulata* broods that release large numbers of eggs in clusters and then develop into new individuals to form a group.

Based on the environmental parameters measurement, the salinity value in the research area ranges from 20 - 33.6‰. The water temperature at the research site ranged from 26.5 - 35.8°C. The pH value of the water at the study site ranged from 7.6 - 8.7. Meanwhile, the total number of individuals of *P. cingulata* species found in the mangrove forest Pangpang Bay is 824 individuals with a study site of 120 m². The calculation of the population density value of *P. cingulata* is 6.86 individuals/m², meaning that there are 7 individuals in an area of 1 m².

The clustering distribution pattern of *P. cingulata* is also influenced by other abiotic environmental factors such as temperature, salinity, and pH. The salinity value is brackish because the research location is where the river flows with sea water. According to Li and Dong (2020) states that the salinity of brackish water ranges from 6 - 30 ppt. The range of salinity values shows ideal conditions for the existence of *P. cingulata* because the position of mangrove forest Pangpang Bay is in the intertidal region with brackish waters. The salinity can still be tolerated by *P. cingulata*. This is supported by the statement of Muraeva *et al.* (2016) that the range of salinity that supports the life of Gastropods is 25 - 40 ‰.

The water temperature at the study site was categorised as medium. This is due to the dense mangrove tree canopy but light intensity can still enter because the research plot area is a semi-open mangrove area. The range of values is still within the ideal limits to support the life of *P. cingulata*. *Pirenella cingulata* is found in many research locations with water temperatures ranging from 30 - 33°C (Li and Dong, 2020). This is also supported by the statement of Moisez *et al.* (2020) and Ariyanto *et al.* (2020b) that the temperature range of 25 - 32°C supports the life of aquatic organisms, so that the research location is still classified as feasible for Gatropods life. The pH value of the water at the study site ranged as neutral. The value range shows an alkaline pH because of its position on the coast, presumably mixed with river water. The range of pH values is still within normal limits. The normal pH value is thought to be the tides that occur every day so that the pH value tends to be stable. Thao *et al.* (2018), the ideal pH for Gastropod life is 6.8-8.5. In general, the measurement results of abiotic environmental parameters show that the mangrove forest area has tolerant environmental conditions and supports the life of *P. cingulata*.

Density value of *P. cingulata* showed a value of 7 individuals per m^2. The density value shows that the population density of *P. cingulata* is greater than the population density value of *P. cingulata* by Bariddah *et al.* (2020) in the mangrove forest area of Pangkalan Sesai Village, Dumai City, Riau Province showing the density value of *P. cingulata* as many as 5 individuals/m². The density value of *P. cingulata* is influenced by two factors, which are competition and migration. Competition occurs due to competition between individuals within one species and between species in obtaining food sources to fulfil their nutrition (Akhrianti *et al.,* 2014). The results of observations at the research site, found competition between individuals of *P. cingulata* as evidenced by the presence of individuals in groups in areas where there is litter. Another competition observed was

the presence of this animal which was found sharing habitat with other gastropod. The competition that occurs is competition in obtaining food sources in the form of litter as a food source in the area but is thought not to cause high mortality of organisms. This causes the number of *P. cingulata* individuals to increase, thus affecting its density value. This is supported by the statement of Zalizahana *et al.* (2022), in addition to substrate conditions, competition for food sources can affect distribution patterns in a population.

Another factor that causes *P. cingulata* population density is migration. Based on the results of observations made during low tide conditions, *P. cingulata* was found in large numbers on the surface of the substrate and under mangrove roots in search of food sources. Ge *et al.* (2014) states that the adaptation of *P. cingulata* during high tide conditions is attached to the roots or stems of mangroves to avoid high tidal currents. Based on this, it is suspected that this animal occurs vertical migration behaviour in mangrove roots due to the tides. *Pirenella cingulata* were found in large numbers due to data collection was done at low tide conditions so that these animals are on the surface of the substrate in search of food sources. This condition is thought to cause the high population density value of *P. cingulata* in the area. Mujiono (2010) states that the genus *Pirenella* is also called climbing gastropods because it is also found attached using its mucous fluid to the trunk or roots of mangrove trees, especially during high tides. This behaviour in addition to avoiding high current waves also aims to avoid predatory fish and crabs.

Based on the description above, the distribution pattern and population density of *P. cingulata* in the area are related to the reforestation programme activities that have been carried out. This is evidenced by the formation of clustered distribution and high density values in an area because these activities are thought to form new habitats that support the life of *P. cingulata*. However, further research is needed to corroborate the researcher's assumptions related to factors that influence distribution and density patterns such as reproductive behaviour, migration and competition. In addition, this research is expected to improve sustainable conservation efforts with appropriate management development strategies. This species tends to be found more frequently in Pangpang Bay than other gastropod species due to the availability of abundant food sources in the form of mangrove leaf litter and mud sediments that contain a lot of organic material that these animals prefer. In addition, Alas Purwo National Park is currently working to collect data on the types of animals that inhabit the mangrove forest area as a database and conservation effort.

CONCLUSION

Distribution pattern of the *P. cingulata* population in the mangrove forest Pangpang Bay is categorised as clustered with a value of 6.19. The population density of *P. cingulata* is 6.86 individuals/m², meaning there are 7 individuals in an area of 1 m². Research should also be conducted to examine the association between mangrove forests and the presence of other gastropods. Continuous research is needed under varying conditions during high tide. This aims to determine the distribution patterns and population density of *P. cingulata* under these two different conditions, as well as the reproductive behavior, competition, and adaptation of this species to high tides.

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