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Sediment Composition, Phytoplankton, and Blood Cockles (*Anadara granosa*) Population

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ABSTRACT

This research aimed to examine the correlation between sediment fractions, phytoplankton biodiversity, and populations of blood cockles (*Anadara granosa*) in marine ecosystems. The study was conducted during February-April 2023 by collecting samples at Gambus Laut Beach, Batubara Regency, Indonesia. Parameters measured included sediment fraction, sediment organic matter content, phytoplankton, blood cockle population, temperature, current speed, water brightness, pH, salinity, and dissolved oxygen. Two sediment fractions were found, namely the sandy mud and muddy sand, and dominated by the muddy sand substrate. The percentage of gravel fraction ranged from 5.2-18.8, sand fraction 36.8-55.7, and mud fraction 25.5-57.1%. The organic material content was 9.9% (station 1), 10.8% (station 2), and 9.5% (station 3). The result established that twelve species of phytoplankton from the classes of Bacillariophyceae (ten species), Cyanophyceae (one species), and Xanthophyceae (one species) were found. Species of *Chaetoceros* sp., *Isthmia* sp., *Pseudo-nitzschia* sp., *Skeletonema* sp., and *Oscillatoria* sp. were found at all stations. The highest abundance of phytoplankton was at station 3 (861.1 cells/L), and the lowest was at station 2 (722.2 cells/L). Water quality parameters were relatively normal and support life in local waters. The statistical analysis results showed no significant correlation between phytoplankton abundance and sediment organic matter content and sediment type (gravel, sand, and mud), where the R values were 0.059, 0.171, 0.191, and 0.326, respectively. There was also no significant correlation between the abundance of blood cockles and organic sediment fraction (gravel, sand, mud), where the R values were 0.272, 0.290, 0.257, and 0.580, respectively.

INTRODUCTION

Understanding the role of sediments in marine ecosystems is essential for managing and conserving these environments. Sediments provide habitats for various marine organisms, including benthic invertebrates, fish, and plants. These habitats are essential for feeding, breeding, and shelter. Sediments are fundamental in forming and maintaining seagrass beds and coral reefs, which are critical for biodiversity. Sediments act as reservoirs for nutrients such as nitrogen, phosphorus, and silica. They can store these nutrients and release them gradually, helping to sustain primary production in the water column. Various microbial processes in sediments, such as nitrification and denitrification, play a key role in the cycling of nutrients. Sediment is a place for decomposing organic materials, both from dead plants and animals, and their waste. This decomposition recycles nutrients back into the ecosystem **(Sarker *et al*., 2021; Jørgensen *et al*., 2022)**.

Phytoplankton are essential to the structure and function of marine ecosystems, supporting life through their roles in primary production, nutrient cycling, carbon sequestration, and climate regulation. Their health and abundance are critical indicators of the overall well-being of marine environments. Phytoplankton play a pivotal role in marine ecosystems, performing functions essential for these environments' health and sustainability. Phytoplankton are the primary producers in marine ecosystems, performing photosynthesis to convert solar energy, carbon dioxide, and nutrients into organic matter. This process forms the foundation of the marine food web. Through photosynthesis, phytoplankton produce oxygen, which is vital for the survival of most marine organisms, including fish, invertebrates, and marine mammals **(Karlusich *et al*., 2020; Lomartire *et al*., 2021)**.

Blood cockles (*Anadara granosa*) are integral to the functioning of marine ecosystems through their roles in habitat formation, nutrient cycling, food web dynamics, and ecosystem engineering. Their ecological, economic, and cultural importance highlights the need for sustainable management and conservation efforts to ensure their continued contribution to marine biodiversity and ecosystem health. Blood cockles play a significant role in marine ecosystems, particularly in coastal and estuarine environments. Blood cockles burrow into the sediment, which helps stabilize the seabed and prevents erosion. Their burrowing activity also influences sediment structure and composition. Blood cockles create habitats for other benthic organisms by burrowing and living in the sediment. Their presence supports a diverse community of invertebrates and microorganisms. Blood cockles' burrowing and feeding activities mix the sediments (bioturbation), enhancing nutrient recycling. This process helps oxygenate the sediment and make nutrients available to other organisms. Blood cockles consume plankton and organic particles from the water column as filter feeders. This filtration process helps maintain water quality and clarity by removing suspended particles and excess nutrients **(Kim *et al*., 2020; Efriyeldi & Effendi, 2022; Rahmatin *et al*., 2024)**. This research examined the correlation between sediment fractions, phytoplankton biodiversity, and populations of blood cockles in marine ecosystems.

MATERIALS AND METHODS

1. Site sampling and collection of samples

This research was carried out in February, March, and April 2023 by taking samples from Gambus Laut Beach, Limapuluh Pesisir District, Batubara Regency, Indonesia. The research location was divided into 3 stations, each with 3 sampling points. The distance between sampling points is 100 meters, and the distance between stations is 200 meters.

2. Sampling procedure

Water, sediment, phytoplankton, and blood cockle samples were collected from 3 stations and carried out 3 times with an interval of one month. The station locations were selected using purposive sampling, considering the differences in natural conditions at each station. Water quality measurements include temperature, current speed, brightness, pH, salinity, and dissolved oxygen.

2.1 Sediment analysis

Sediment grain size for the sand and gravel fractions was analyzed by using the wet sieving method **(Alekseeva & Sval'nov, 2005; Logemann *et al*., 2023)**, while the mud fraction was analyzed using the pipette method **(Konert & Vandenberghe, 1997; Ayeku *et al*., 2021)**. The sample was placed in a cup containing the wet sample and dried in an oven at 105°C (one day). The sample was weighed and added with sufficient hydrogen peroxide solution (3-5%). Determining sediment types in the laboratory was referred to **(Rifardi, 2001; Rifardi & Mubarak, 2022)**.

Sediment samples were taken to the laboratory and placed in a cup before weighing. The samples were weighed with a wet weight of 100 grams for each sample using an analytical balance. The sample was placed in a cup, then added with sufficient 3% peroxide solution, and left for 1 day so that the particles could separate from one another. The sediment samples were sieved using a multilevel sieve to obtain different sediment fractions. The sample collected in each sieve was taken and placed in an aluminum foil container previously weighed and labeled. The sediment fraction that still passed was placed in a cylindrical tube for mud fraction analysis. The sediment fraction obtained according to the mesh size was dried using an oven for 24 hours. Then, the sediment fraction was weighed for each sample.

The sediment grains that passed through the filter and the water were collected in a container and put into a 1000ml cylindrical tube. The samples were waited for 5 minutes to obtain the Ø5 sediment fraction using a volumetric pipette with predetermined limits according to the depth of 10 and 20ml. After the first 5 minutes have been completed and the sample has been collected, the samples were waited for 15 minutes and then the sediment samples were collected again for the Ø6 sediment fraction. Finally, after the stopwatch showed 30 minutes, the Ø7 sediment fraction was collected. Each water sample that had been collected was placed into a labeled aluminum foil container and then dried in an oven for 24 hours. The dry sample was weighed along with the container. The cumulative weight of all groups of sample sediment grains was recorded, and the results were entered into the fraction calculation table.

Determination of the sediment fraction was carried out by using Sheppard's triangle calculation method. Calculations were based on the proportion of gravel, sand, and mud particle size content **(Sheppard, 1954; Wan *et al*., 2020)**. Surface sediments were classified according to the Sheppard diagram. The classification system was based on median diameter (MD). The Sheppard diagram is an example of a triple diagram (a tool for graphing three units) of a 100% component system. These components are the percentage of gravel, sand, and mud that fills the sediment. Each sediment sample was plotted as a point within or along the diagram's sides, depending on its specific grain size composition. Sheppard divided a triple diagram into 10 classes to classify sediment samples. Total organic matter content was analyzed using the loss on ignition (LOI) method. Organic matter content is calculated using the formula:

$$\mathrm{BOT} = \frac{(\mathrm{Wt} - \mathrm{C}) - (\mathrm{Wa} - \mathrm{C})}{\mathrm{Wt} - \mathrm{C}} \, x \, 100\%$$

Where:
Wt = total weight (crucible + sample) before burning, Wa = total weight (crucible + sample) after burning, and C = weight of empty crucible.

2.2 Phytoplankton analysis

Water sampling for phytoplankton analysis was carried out at intervals during the day between 11.00-15.00. The plankton net used has a mesh size specification of 25, a plankton net mouth diameter of 30cm, and a plankton net trapezoidal height of 75cm. The sampling method was carried out by referring to **Tomas (1997) and Verlencar *et al*. (2004)**. The collection bottle was installed at the back or bottom of the plankton net. The total volume of filtered water was approximately 100 liters. A 125ml water sample containing filtered phytoplankton was placed into a collection bottle and preserved using 3-4 drops of pure Lugol (4%) solution. Samples were observed in the laboratory under a microscope to determine the species and abundance of phytoplankton. Phytoplankton observations were carried out using the sweep method and repeated three times. Phytoplankton abundance was calculated using the formula from **APHA (1989)**, namely:

$$\text{Phytoplankton abundance (cells/l)} = \mathrm{Z} \times \frac{\mathrm{X}}{\mathrm{Y}} \times \frac{1}{\mathrm{v}}$$

Where:
Z: Number of phytoplankton individuals found
X: Volume of sample water in the sample bottle (125ml)

Y: Volume of 1 drop of sample water (0.06ml)
V: Volume of filtered water (100L).

2.3 Abundance of blood cockles analysis

Abundance is the number of individuals per unit area or unit volume. Samples were collected per station using 1 transect/station consisting of 3 plots, each plot measuring 1 x 1m^2. Abundance of blood cockles was calculated by using the following formula **(Krebs, 20214)**.

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

Where:
Di = Abundance of the ith species of the individual (ind/m²),
ni = Number of individuals of the ith species obtained and
A = Plot area of the ith species found (1 m²).

2.4 Data analysis

Data obtained from direct measurements in the field and laboratory results were analyzed statistically (minimum, maximum, mean, standard deviation, skewness, kurtosis, Pearson correlation analysis, and analysis of variance), discussed descriptively, and compared with relevant research results and theories.

RESULTS

1. Fraction and type of sediment

From the analysis of sediment fractions at each research station, two types of sediment fractions were found, namely sandy mud and muddy sand fractions. The classification of sediment types was based on the proportion of gravel, sand, and mud content according to Sheppard's triangle. A muddy sand substrate dominates this marine sediment. The percentage of gravel fraction ranged from 5.2-18.8, sand fraction 36.8-55.7, and mud fraction 25.5-57.1% (Table 1).

2. Sedimentary organic matter

The percentage of organic matter content in the sediment found at each station was 9.9% (station 1), 10.8% (station 2), and 9.5% (station 3). The highest sediment organic matter content was found at station 2, sampling point 1, with a percentage of 12.78%. Meanwhile, the lowest organic material content was found at station 3, sampling point 3, with a percentage of 7.11%. The organic matter at the research location has an average range of 9.55-10.80%. The standard deviation values from the three research stations were quite small, so the data obtained were quite accurate (Table 2).

Table 1. Percentage fraction (%) and sediment type at each station study

Station	Sampling points	Sediment fraction (%)			Type of sediment
		Gravel	Sand	Mud	
1	1	14.011	42.852	57.143	Sandy Mud
	2	18.752	48.363	51.704	Muddy Sand
	3	16.022	46.914	53.075	Sandy Mud
	Mean	16.262	46.043	53.974	
	Std. Deviation	1.943	2.332	2.309	
2	1	11.653	40.895	47.452	Sandy Mud
	2	8.041	36.852	55.113	Sandy Mud
	3	18.412	50.823	30.762	Muddy Sand
	Mean	12.702	42.857	44.442	
	Std. Deviation	4.298	5.869	10.166	
3	1	5.203	50.984	43.823	Muddy Sand
	2	18.843	55.691	25.474	Muddy Sand
	3	14.214	52.502	33.293	Muddy Sand
	Mean	12.753	53.059	34.197	
	Std. Deviation	5.663	1.961	7.518,	

Table 2. Sedimentary organic matter content (%) at every research station

Station	Organic matter content (%)	Average + Deviation Standard
1	10.891	9.995 ± 0.931
	9.032	
	10.062	
2	12.782	10.802 ± 2.450
	11.563	
	8.062	
3	12.001	9.556 ± 2.443
	9.552	
	7.114	

3. Phytoplankton identification

Ten phytoplankton species were found in the Bacillariophyceae class, one Cyanophyceae, and one Xanthophyceae. Of the three classes, the species most commonly found was from the Bacillariophyceae class (Table 3).

Table 3. Classification of phytoplankton found at all research stations

Class	Ordo	Family	Species
Bacillariophyceae	Pennales	Fragilariaceae	*Asterionella* sp.
	Aulacoseirales	Aulacoseiraceae	*Aulacoseira* sp.
	Chaetocerotanae	Chaetocerotaceae	*Chaetoceros* sp.
	Biddulphiales	Biddulphiaceae	*Isthmia* sp.
	Bacillariales	Bacillariaceae	*Nitzschia* sp.
	Naviculales	Pleurosigmataceae	*Pleurosigma* sp.
	Bacillariales	Bacillariaceae	*Pseudonitzschia* sp.
	Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia* sp.
	Thalassiosirales	Skeletonemaceae	*Skeletonema* sp.
	Thalassionematales	Thalassionemataceae	*Thalassionema* sp.
Cyanophyceae	Oscillatoriales	Oscillatoriaceae	*Oscillatoria* sp.
Xanthophyceae	Mischococcales	Centritractaceae	*Centritractus* sp.

4. Distribution of phytoplankton species

The most abundant phytoplankton species were found at station 2 with nine species and the fewest at station 3 with seven species. Species of *Chaetoceros* sp., *Isthmia* sp., *Pseudo-nitzschia* sp., *Skeletonema* sp., and *Oscillatoria* sp. were found at all stations. The distribution of phytoplankton at each station is presented in more detail in Table (4).

Table 4. Distribution of phytoplankton species at each research station

No.	Class	Species	Station 1	Station 2	Station 3
	Bacillariophyceae	*Asterionella* sp.	+	+	-
		Aulacoseira sp.	+	-	-
		Chaetoceros sp.	+	+	+
		Isthmia sp.	+	+	+
		Nitzschia sp	-	+	+
		Pleurosigma sp.	-	+	-
		Pseudonitzschia sp.	+	+	+
		Rhizosolenia sp.	-	+	-
		Skeletonema sp.	+	+	+
.		*Thalassionema* sp.	-	-	+
.	Cyanophyceae	*Oscillatoria* sp.	+	+	+
.	Xanthophyceae	*Centritractus* sp.	+	-	-

+ = present, - = absent

5. Phytoplankton abundance

The highest abundance of phytoplankton was at station 3, 861.11 cells/L, and the lowest was at station 2, 722.22 cells/L. However, it can be said that the abundance of phytoplankton at stations 1, 2, and 3 was not significantly different. The results of calculating phytoplankton abundance can be seen in Table (5).

Table 5. Phytoplankton abundance (cells/L) at each research station

Station	Sampling points	Abundance (cells/l)	Average + Deviation Standard
1	1	708.331	826.575 ± 186.587
	2	1,041.673	
	3	729.172	
2	1	625.004	722.227 ± 118.466
	2	854.175	
	3	687.502	
3	1	708.333	861.114 133.942
	2	916.674	
	3	958.334	

6. Blood cockles abundance

The highest abundance of blood cockles was at station 3, namely 196 individuals/m², and the lowest was at station 1, 158 individuals/m² with a standard deviation of 118.466- 186.587.

Table 6. Blood cockle abundance (individuals/m^2) at each research station

Station	Sampling points	Abundance (individuals/m2)	Average + Deviation Standard
1	1	174	158.000 ± 23.516
	2	131	
	3	169	
2	1	163	181.000 ± 15.875
	2	193	
	3	187	
3	1	182	195.666 ±12.622
	2	198	
	3	207	

7. Water quality

The water temperature ranged from 28.3-31.3°C, the lowest tempreature at station 1 during the third month with was 28.3°C and the highest at station 3 during the second month was 31.3°C. The current speed ranged between 13-23cm/ s, the lowest at station 1 and station 2 during the second month with was 13cm/ s, and the highest at station 1 during the first month was 23cm/ s. The water brightness ranged from 30-63.3cm; the lowest was at station 2 during the second month with an average of 30cm, and the highest was at station 1 during the third month with a value of 63.3cm (Table 7).

Table 7. Results of water quality measurements at each research station

Parameter	Unit	Station	Average	Average + Deviation Standard
Temperature	°C	1	29.533	29.633 +0.121
		2	29.600	
		3	29.767	
Current speed	cm/s	1	19.333	18.999 +0.577
		2	18.333	
		3	19.333	
Water brightness	cm	1	43.600	45.089 +2.579
		2	43.600	
		3	48.067	
pH	-	1	7.867	7.878 +0.084
		2	7.800	
		3	7.967	
Salinity	‰	1	24.000	26.000 +1.763
		2	26.667	
		3	27.333	
Dissolved oxygen	mg/L	1	7.067	7.056 +1.183
		2	6.867	
		3	7.233	

DISCUSSION

1. Sediment

This study's sediment organic matter levels ranged from 7.114-12.782%. Sediment organic matter levels in the range of 5-14% are included in the low-medium criteria. The high or low levels of organic matter content in sediment are greatly influenced by the type of sediment fraction at the research location. The mud fraction contains more organic material because the density of the sediment pores is relatively narrow, so organic material is easily trapped. Meanwhile, the sand fraction type binds less organic material because the sediment density level is wide, making it easier for currents to release organic material from the sediment. The lack of influence of currents can also influence the high concentration of organic matter in waters where organic matter settles more quickly in relatively calm waters **(Beaudoin, 2003; Arndt *et al*., 2013; Nedi *et al*., 2018)**.

From the sediment fraction analysis results, two types of sediment fractions were found, namely the sandy mud fraction and the muddy sand fraction. The percentage of gravel fraction ranges from 5.2-18.8, sand fraction 36.8-55.7, and mud fraction 25.8-57.1%. The percentage of organic matter content in the sediment ranges from 7.1-12.8%. When compared with data from previous research, it can be said that the condition of the sediment at the research location is still in a relatively natural condition **(Noviadi, 2016; Nedi *et al*., 2018; Prartono *et al*., 2023)**.

2. Phytoplankton

Of the three classes Bacillariophyceae class, Cyanophyceae, and Xanthophyceae, 12 species of *Chaetoceros* sp., *Isthmia* sp., *Pseudo-nitzschia* sp., *Skeletonema* sp. and *Oscillatoria* sp. were found at all stations. The number of this species is relatively small compared to what researchers previously reported. **Mahary *et al*. (2023)** reported 30 species found in Batubara Regency waters, and **Riza *et al*. (2021)** found 32 species. The author suspects that the difference in the number of phytoplankton genera in this research when compared with previous research is more due to differences in sampling time, sampling zone, and sampling location. Apart from that, the level of identification accuracy will also have an influence.

In this study, it was found that there was no relationship between phytoplankton abundance and sediment organic matter content and sediment type (gravel, sand, and mud). The statistical analysis results show that the respective R values are -0.558, 0.360, 0.332, and -0.175. This condition can be understood when the interaction between sediment and phytoplankton is dynamic and influenced by various physical, chemical, and biological factors. The relationship between sediment and phytoplankton abundance can be complex and influenced by various environmental factors. Sediments at the bottom of water often contain nutrients such as nitrogen and phosphorus. When these sediments are disturbed and uplifted into the water column, these nutrients can become available to phytoplankton, leading to increased phytoplankton abundance. Increased sediment in the water column can increase water turbidity, reducing sunlight penetration. Phytoplankton need light for photosynthesis, so high turbidity can reduce the photosynthesis rate and the abundance of phytoplankton **(Philippart *et al*., 2000; Rao *et al*., 2018; Lee *et al*., 2019)**.

Some species of phytoplankton may prefer certain conditions provided by certain sediment types. For example, larger phytoplankton may be more resistant to turbidity than smaller phytoplankton. In many aquatic ecosystems, sediment and phytoplankton abundance can fluctuate seasonally. For example, during the rainy season, soil erosion may increase the amount of sediment in waters, while phytoplankton abundance may increase during the summer when temperature and sunlight increase **(Domingues *et al*., 2012).** The weakness of this relationship could be due to relatively strong seawater currents. The water column above the local sediment flows from another place, so the influence of the underlying sediment is relatively small on the phytoplankton population in the water column above it.

3. Blood cockles

Sediment is one of the factors that influence the life of blood cockles because it acts as a place for the blood clams to live. Apart from that, sediment also functions as a component that can accumulate nutrients and organic materials that support the needs of blood cockles **(Jeffrey *et al*., 2005)**. Sediment distribution is usually influenced by marine physical factors such as currents, waves, and water discharge, among other factors. Species such as *Anadara* sp, *Perna* sp., and *Marcia* sp. were found in muddy sand substrates, these three species have habitats with a sandy or slightly muddy texture. This type of substrate is essential for the development of benthic organisms, and sand tends to facilitate the migration and movement of organisms to other places in search of food. The substrate in the form of mud usually contains little oxygen, and therefore, the organisms that live in it must be able to adapt to these conditions **(Lai *et al*, 2020; Jaowatana *et al*., 2024)**.

Overall, sediments are essential in determining the abundance and health of blood cockle populations. Blood cockles generally live at the bottom of muddy waters or muddy sand. Sediment provides the necessary substrate for blood cockles to hide and search for food. Stable and suitable sediment is essential for the survival and growth of blood cockles. Sediment can be a source of nutrients for blood cockles through the decomposition process of organic material. These nutrients can support the growth of phytoplankton, which then becomes a food source for blood cockles **(Rahmah *et al*., 2019)**.

The relationship between sediment particle size and cockles can be quite significant, as it directly affects their habitat and survival. Cockles are filter feeders that live buried in the sediment of coastal and estuarine environments. Cockles can burrow into sediment to varying depths depending on particle size. They prefer fine-grained sediments (silts and clays) or medium-grained (sand), as these provide stability and support for burrowing. Coarse sediments (gravel and pebbles) are typically too large and unstable for cockles to burrow into effectively. Fine sediments tend to have lower permeability, which can lead to reduced oxygen availability in deeper layers **(Eliseev, 1983; Anta *et al*., 2013)**. In this study, the statistical analysis results showed a negative and weak relationship between sediment organic matter levels and the abundance of blood cockles, namely R = -0.234. This is thought to be related to the particle size and type of organic material contained in the sediment. Blood cockles cannot utilize relatively large particles of sedimentary organic material, so they have no real effect. Furthermore, it also appears that there is no relationship between the abundance of blood cockles and the sediment fraction (gravel and sand), where the R values are -0.214, 0, and 251, respectively. However, there is a negative relationship with the mud sediment fraction, where R = -0.562.

4. Water quality

The water temperature ranges from 28.3 to 31.3°C, current speed ranges between 13 and 23cm/ s, water transparency ranges from 30 to 63.3cm, pH ranges from 7.800 to 7.967, salinity from 24.000 to 27.333 ‰, and dissolved oxygen from 6.867 to 7.233mg/ L — all considered to be within normal conditions. **Mahary et al. (2023)** reported similar water quality conditions in the waters of Batubara Regency, as follows: salinity was around 34.0ppt, temperature ranged from 28.0 to 29.0°C, brightness from 50.0 to 53.0 cm, pH from 8.0 to 8.2, dissolved oxygen from 5.2 to 5.4mg/ L, and alkalinity from 124 to 125mg/ L. A similar observation was also reported by **Riza *et al*. (2021)** in the waters of a neighboring regency, Rokan Hilir, where salinity was around 34.0ppt, temperature ranged from 28.7 to 29.0°C, brightness from 50.0 to 55.0cm, pH was 8.0, dissolved oxygen ranged from 4.4 to 6.1mg/ L, and alkalinity from 120 to 125mg/ L.

When compared with the Conformity Assessment Scheme of Indonesian National Standards in the Agriculture, Plantation, Livestock, and Fisheries Sector **(RNSA, 2022)**, these figures indicate that the water quality in both regions is still within normal limits. According to this standard, the acceptable range for seawater quality is as follows: salinity 10–35ppt, temperature 28–30 °C, brightness ≥60cm, pH 7.5–8.5, dissolved oxygen >3.0mg/ L, and alkalinity 80–150mg/ L.

CONCLUSION

In this study, it is noted there was no correlation between phytoplankton abundance and sediment conditions. The statistical analysis results show no relationship between phytoplankton abundance and sediment organic matter content and sediment type (gravel, sand, and mud), where the R values are 0.059, 0.171, 0.191, and 0.326, respectively. There is also no relationship between the abundance of blood cockles and organic sediment fraction (gravel, sand, mud), where the R values are 0.272, 0.290, 0.257, and 0.580, respectively. It is recommended that further research be carried out by examining seawater current aspects in more detail. For example, a longer research duration, a wider research area, current patterns (surface and bottom currents), and current direction, so that the true correlation between sediment conditions and the abundance of phytoplankton and blood cockles can be understood.

AUTHORS' CONTRIBUTIONS

Conceptualization, methodology, formal analysis, resources, writing—original draft preparation, writing—review and editing, supervision, and funding acquisition (IE), formal analysis, writing—original draft preparation, writing—review and editing (BM), validation, supervision, and funding acquisition (AM), data curation, visualization, project administration (HE), and software, investigation, visualization, formal analysis (TT). All authors read and approved the final manuscript.

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