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Distribution Analysis of Green Mussels (*Perna viridis*) in Banyuurip Village, Ujung Pangkah District, Gresik Regency

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Abstract. The aim of the research was to determine the Distribution analysis of *Perna viridis* diversity based on the suitability map for green mussel cultivation, analysis of community perceptions and the condition of water bodies. *Perna viridis* aquaculture is suitable for the waters of Banyuurip village based on the variables of sea depth, sea surface temperature, chlorophyll a concentration, and substrate radiance data. Heavy metal content of Pb is located and distributed in polluted areas. It was found that the potential for green mussel aquaculture is greater in warm water habitats, i.e. closer to the coast. In addition, the northeast was identified as a suitable habitat for green mussels. The mid-ocean area in the north-west is of low suitability due to the lack of substrate and chlorophyll. Analysis of community attitudes and behaviour showed that people remain enthusiastic about green mussel farming, although green mussel shell waste remains an environmental problem. Heavy metal analysis of green mussel samples showed that green mussels are still safe for consumption. Therefore, the main conclusion is that the habitat of *Perna viridis* in the waters of Banyuurip Village still has potential for cultivation, but the waters must be free from pollution.

1 Introduction

Coastal areas are areas adjacent to the coastline with increasingly dense concentrations of human population, as well as residential development, and growing socio-economic activities.[1-2]. One of the potentials of coastal areas is the green mussel (*Perna viridis*), a

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species of bivalve mollusc group that is green in colour. According to Sea et al [3], in order to understand this species of mollusk, it is necessary to measure its distribution habitat. This is because these molluscs breathe and produce CO_2. Green mussels are an important resource for the community due to their high nutritional value. Green mussels are a source of high protein content and an excellent source of fat and carbohydrates [4]. As a commercial food source, green mussels must be of a high quality, meeting various standard criteria such as high meat content with an attractive appearance, and free from contaminants, such as pathogenic bacteria (*E. coli, Salmonella* spp.), heavy metals, and toxic or harmful algae. This is because the biological nature of green mussels when it feeds is to filter water (filter feeding).

The research question is that is therefore necessary to monitor the different ways in which pollutants are introduced into the aquatic environment. The green mussel is known for its characteristic fast growth rate and high tolerance to various environmental conditions, as well as its ability to live and thrive at high population density. This species is very economically viable for aquaculture systems and it plays an important role in ensuring food security and nutrition for society in the future. Furthermore research hypothesis is that as [5] stated that aquaculture is widely recognised as an important strategy for food security and poverty eradication. However, the problem is that green mussels in the study area are threatened by water pollution from various types of water discharges from residential areas, milkfish ponds and industrial areas. Doubts of consumers and producers on whether green mussels are fit for consumption, so that food-borne diseases become a problem of aquaculture in the study area. According to [6], the heavy metal lead (Pb) found in waters can directly and also directly endanger the life of aquatic organisms. Aquatic organisms directly and also indirectly are threaten human health through contamination of the food chain. In order to address the concerns of the residents of the study area about Pb contamination of *Perna viridis*, information on the distribution of its habitat, including research on water pollution and Pb content, as well as its bottom substrate is needed.

The aim of this research is to determine the Distribution analysis of *Perna viridis* in order to map the aquatic area that can support potential exploitation areas and areas worthy of protection. (I change the aim of this research is the aim of this study is to determine the analysis distribution of *Perna viridis* in order to map the aquatic area that can support potential exploitation areas and areas worthy of protection).

2 Materials and methods

2.1 Study Area

Materials and methods should focus on the procedures and data analysis. For the field study, it is better if the study area is included (Figure 1).

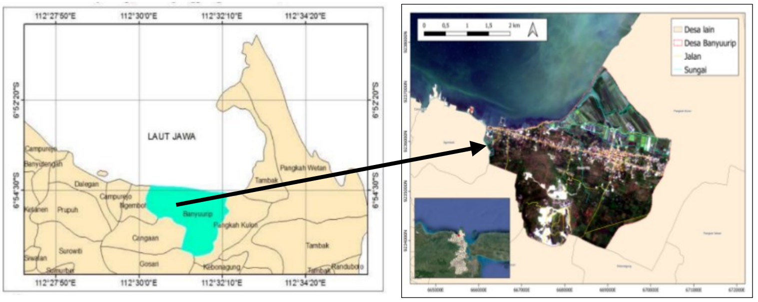

Fig. 1. Study area.

To restore this green mussel as a food source, innovative efforts are needed to protect it from the threat of destruction, especially the destruction of its habitat. Using the principle of sustainability, the process of integrating research methods must be done with the following management principles:

a) From the ecological dimension, it is necessary to manage the green mussels so that this alternative food source becomes a "healthy food", safe for consumption, healthy and with nutrients that can be used for growth;
b) From the economic dimension, the utilisation of green mussels as an economic potential can be used to increase community income and regional income in Gresik Regency.
c) The social dimension is that management emphasises on increasing community access to green mussel resources equally for the entire community.

The model that was used in this study included: a) spatial approach related to spatial variables to determine potential green mussel habitat areas; b) green mussel habitat ecosystem, which includes physical and chemical water quality; c) measurements: abundance, dominance, species, diversity, habitat, species, and; d) community attitudes and behaviour. These could be described using GIS. GIS applications can be used to identify the suitability of areas for various coastal activities, including mariculture [7], marine tourism, settlements or harbours.

2.2 Methods

Methods to analyse spatial planning, determine physical and chemical water quality, measure morphometry of green mussels and measure community attitudes and behaviours are described below:

2.2.1 Methods for Measuring Spasial Planning

The GIS method was used to map green mussel habitats in order to identify potential areas with green mussels that are suitable for development and areas that need to be conserved to protect green mussels in the future. The coastal land cover classification uses SNI data on land cover classification number 7645 of 2010.

2.2.2 Methods for Determining Physical and Chemical Water Quality

The analytical method with in situ measurements was carried out using a thermometer to measure temperature and a salinometer to measure salinity. A pH meter was used to measure pH parameters. A DO meter was used to measure oxygen content and a Secchi disc to measure Transparancy. Figure 2 shows the location of station 1 to 5 for physical san chemical water quality.

2.2.3 Method for Measuring the Morphometry of Perna viridis

The morphometry of green mussels was measured by measuring the length and width of the shell at five measuring stations. Meanwhile, the metal content of the green mussels was measured by measuring the shell roundness index and sediment grain size including sediment type.

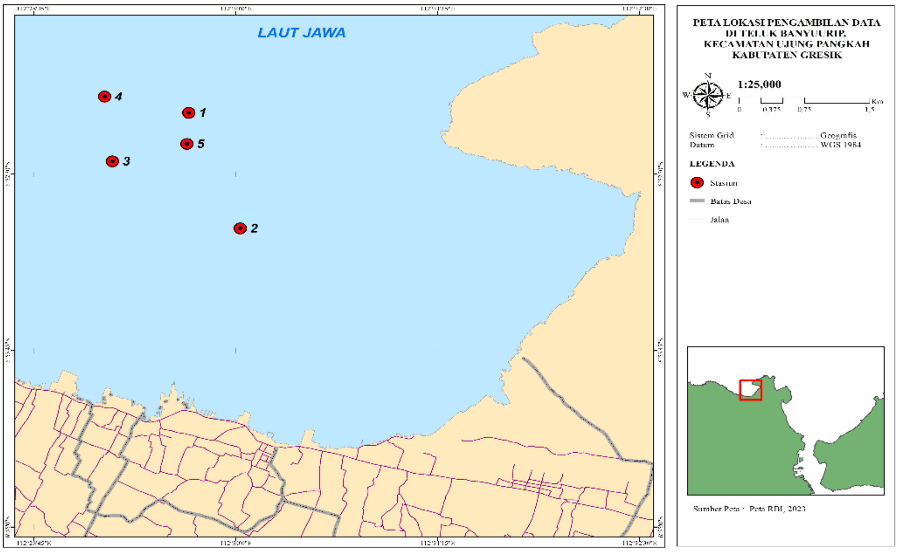

Fig. 2. The distribution locations of measurement stations.

2.2.4 Method for Measuring Attitude and Behaviour

The procedure for using the PLS analysis method was carried out by interviewing respondents to find out the community's assessment and perception of the use of green mussels and community participation in efforts to protect water areas for green mussel habitat cultivation as an alternative food source and livelihood. There are 60 respondents consisted of 15 respondents for official governments, and the rest is local people lived in coastal area who produce and consume green mussels

2.3 Data Collection and Analysis

2.3.1 Analysis of Physical and Chemical Water Quality Collection and Analysis

The results of water quality measurements in Banyuurip Village, Ujung Pangkah District, Gresik Regency at each observation station are presented in the following Table 1. The parameters measured were Transparancy, temperature, salinity, pH and dissolved oxygen.

2.3.2 Transparancy Collection Data and Analysis

The measurement results of the transparency (water clarity) of the water in Banyuurip Village ranged from 0.82 to 1.2 metres. The highest Transparancy value was found at station 1, which is 1.2 metres, and the lowest Transparancy value was found at station 5, which is 0.82 metres. This range of values is not included in the tolerance limit according to the quality standards of the Decree of the Minister of Environment No. 51 of 2004 because the value of water Transparancy in Banyu Urip Village is less than 3 metres. The low Transparancy of the water in Banyu Urip Village is believed to be caused by sedimentation from the Bengawan Solo estuary.

Table 1. Water quality measurement in Banyuurip Village.

Parameters	*Stations*					*Quality Standard*
	1	2	3	4	5	
Transparancy (m)	1,2	0,85	1,04	1,04	0,82	>3 m
Temperature (°c)	31.6±0.58	30.3±0.58	30.6±0.58	30.6±0.58	30.3±0.58	28-30°C
Salinity (‰)	32.6±0.58	32.6±0.58	32.3±0.58	30.6±1.15	32.3±0.58	33-34‰
pH	7.91±0.19	7.74±0.18	7.95±0.11	7.8±0.04	7.67±0.06	7-8,5
Dissolved oxygen (mg/L)	20.16±0.40	28.06±0.45	16.03±1.17	37.93±0.45	26.96±0.61	>5 mg/L

2.3.3 Temperature Collection Data and Analysis

The results of temperature measurements in the waters of Banyuurip Village ranged from 30.3°C to 31.6°C. The highest water temperature was recorded at station 1 with a value of 31.6°c and the lowest temperature value was recorded at stations 2 and 5 with a value of 30.3°c. This value range is not included in the tolerance limit according to the quality standard of Decree of the Minister of Environment No. 51 of 2004 because the optimum quality standard value for water temperature ranges from 28°C to 30°C, while the value of water temperature in Banyuurip Village was higher than the quality standard value, which is more than 30°C.

2.3.4 pH Collection Data and Analysis

The results of pH measurements in the waters of Banyuurip Village ranged from 7.67 to 7.95. The highest pH value was recorded at station 3 with a value of 7.95. and the lowest pH value was recorded at station 5 with a value of 7.67. According to the quality standard of the Decree of the Minister of Environment No. 51 of 2004, the pH of water is considered optimal if the value is between 7-8.5 and the pH of the waters of Banyuurip Village was still within the tolerance limit.

2.3.5 Dissolved Oxygen (DO) Data Collection and Analysis

The data collection and analysis of DO showed in the waters of Banyuurip Village ranged from 16.03-37.93 mg/L. The highest water DO was found at station 4 with a value of 37.93 mg/L. and the lowest pH value was found at station 3 with a value of 16.03 mg/L. According to the quality standard of the Decree of the Minister of Environment No. 51 Year 2004, the DO of water is considered optimal if the value is more than 5 mg/L, and the DO of the waters of Banyuurip Village had a DO value of more than 5 mg/L.

2.3.6 Spatial Planning collection data and Analysis

The map of suitability for green mussel cultivation in Banyuurip Village uses geospatial variables that support green mussel habitat. The variables used were sea depth from ETOPO, sea surface temperature from Landsat TIRS, chlorophyll a concentration and soil substrate from Sentinel-3. The variables used were tagged and then grouped according to percentiles to divide suitability levels. The resulting suitability map shows two clusters of high aquaculture suitability: coastal and north offshore, which are full of chlorophyll and rich in substrate. Several studies [8-11] have shown that green mussels grow well in areas that are not too deep but are constantly inundated with seawater and have warm coastal temperatures, high bottom substrate, and dense concentrations of chlorophyll. However, previous studies have generally used coarse resolution or secondary data to obtain temperature, substrate and chlorophyll data. The coarse resolution makes mapping at a high village scale inappropriate. In this study, Sentinel-3 data were processed to obtain substrate and chlorophyll data, and temperature data were obtained from Landsat TIRS. The purpose of using this higher resolution data was to produce a more accurate village scale map. Therefore, this research processed data with higher resolution data to map the suitability of green mussel cultivation in Banyuurip village.

In this research, geospatial analysis used four variables to calculate depth suitability, sea surface temperature, chlorophyll a concentration and seafloor substrate. Depth data were obtained from [12]. ETOPO data has a low resolution of 10 km, but was used because it can show ocean depth information. This data was merged with NASA SRTM data and then resampled and averaged neighbours to create 200 metre resolution ocean depth data. Sea surface temperature data were obtained from Landsat 8 TIRS band 10 of the 2022 median composite [13]. These data have a resolution of 100 m, but were resampled to match the resolution of the 200 m depth data. Chlorophyll a and substrate data were derived from Sentinel-3 data. Chlorophyll a was obtained using the OC4Me algorithm, which produces chlorophyll-a concentrations in grams/litre [14]. The temporary substrate used was the Sentinel-3 band 8 radiance. All data were masked to appear only in the sea where green mussels are grown. All data were scored on the basis of the criteria proposed by [15]. The difference is that in this study, instead of discrete values, the values were detected. The characterisation value was done by using a fuzzy method with a range of 0-100, where 100 is ideal and 0 is not ideal. Only in the final stage, the new classification, were the data grouped into 4 classes: very suitable, suitable, conditionally suitable and not suitable. The division into 4 classes is not based on the total score but on the quantiles. This means that total scores in quantiles 3 and above are highly suitable and those in quantiles 1 and below are not suitable. All processing was done using Google Earth Engine (GEE). The data source was also taken from GEE. GEE was used because it has a lot of geospatial data that can be used for geospatial analysis. GEE was also used because it can process a lot of data without using a lot of computation on a personal computer.[16].

2.3.7 Morphometric Collection Data and Analysis of Perna viridis

Morphometric characters are one of the measures/observations that can be used to distinguish one species from another. Changes in morphological or genetical characters can be caused by geographical differences or environmental differences. Morphometrics is a method of measuring the external shape of the body, which is used as a basis for comparing the size of green mussels (*Perna viridis*), such as width, standard length, height and others. Morphometric measurements are useful for knowing the growth patterns, feeding habits and groups of *Perna viridis* and as a basis for fish identification [17]. Morphometric characters that are often used for measurement include total length, standard length, claw length, body height and width, fin height and length, and eye diameter [18].

2.3.8 Collection and Analysis Data to Measure Attitude and Behaviour

Collected sample on the site was cleaned by using distiled water, without break the *Pernva viridis* organs. All sample was photographed to backup all sample data in original condition (after the sample took on the observation sites). *Perna viridis* sample was measured by using vernier calipers, and re-measured on ImageJ based on each photographed samples.

Station 1 was occupied by green mussels ranging in size from 32-41 mm to 52-61 mm. Station 2 was occupied by mussels in the 32-41 mm to 62-71 mm size class. Station 3 was occupied by those in the 12-21 mm and 32-41 mm to 52-61 mm size classes. Station 4 was inhabited by those in the 22-31 mm to 52-61 mm size class. Station 5 was inhabited by the 22-31 mm to 82-91 mm size class (Figure 3).

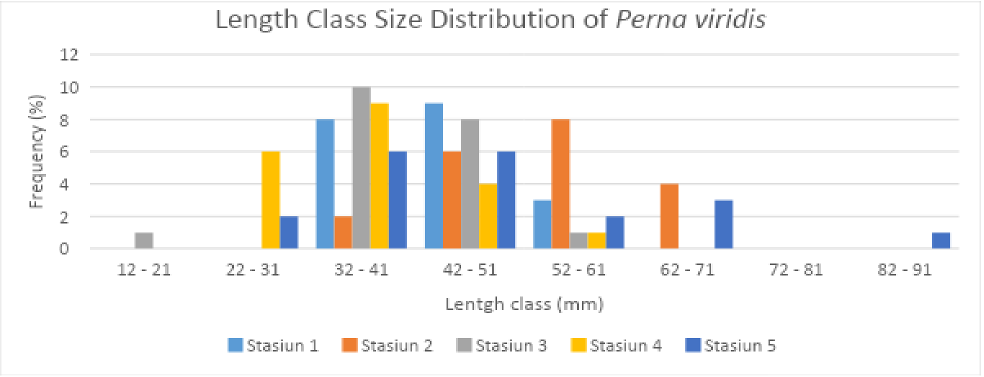

Fig. 3. Length class distribution chart.

The results of the analysis also showed that the 12-21 mm size class with a frequency value of 1% was dominant only at station 3. The distribution of the size class 22-31 mm was dominant at station 4 with a frequency of 6%. The distribution of the 32-41 mm size class was dominant at station 3 with a frequency of 10%. At this size, green mussels are already included in the harvestable size category. This is due to the fact that the width of adult green mussels is generally half their length, so the 40-60 mm range is included in the adult size [19]. The distribution of the 42-51 mm size class was dominant at station 1 with a frequency of 9%. Then the distribution of the 52-61 mm size class was dominant at station 2 with a frequency of 8%. The 62-71 mm size class was dominant at station 2 with a frequency of 4%. Meanwhile, the 82-91 mm size class was dominant at station 5 with a frequency of 1%.

2.3.9 Socio-Economic Collection and Analysis

In order to conduct the PLS analysis, data were collected by means of questionnaires with a total of 59 respondents. The purpose of distributing this questionnaire was to find out the response of the community in Banyuurip Village to the innovation of utilising green mussel shells. This is because during the FGD with the community, it is hoped that the shell problem can be resolved immediately, because it damages the environment.

Based on data on demographic characteristics of 59 respondents, the average age was 44.46 years old with the age of the youngest respondent being 23 years old and the oldest respondent being 72 years old, but most respondents were between 30 and 39 years old (23.7%), 30.5% were between 40 and 49 years old, and 25.4% were between 50 and 59 years. In term of gender, there were more male respondents (88.1%) than female respondents (11.9%). In terms of educational attainment, a large number of respondents (35.6%) had completed high school. Regarding the type of occupation of the 59 respondents, 83.1% were fishermen, and a smaller percentage of other respondents had various types of occupations.

Regarding the monthly income, it can be seen that most of the respondents have an income of less than one million rupiah per month (32.2%), 30.5% have an income of more than two to three million rupiah per month, and a smaller percentage of other respondents have varying income levels. Based on the category of each variable, the most dominant is for the perception of green mussels as economic potential, 52.5% of respondents have a very high perception of green mussels as economic potential, for the perception of uneven distribution of green mussels, 45.8% of respondents have a very high perception of uneven distribution of green mussels, for the perception of green mussel shells that have not been maximally utilised, 59. 3% of respondents who have a very high perception for green mussel shells have not been maximally utilised, for perceptions about green mussel shells are not clear as many as 62.7% of respondents who have a very high perception for green mussel shells are not clear about their usefulness, and for perceptions about green mussel shells for flood control concrete mix as many as 45.8% of respondents who have a high perception for green mussel shells for flood control concrete mix, and 44.1% of respondents who have a very high perception for green mussel shells for flood control concrete mix.

Furthermore, based on the data collected, it can be stated that all items are considered reliable as measures of the observed variables. This is indicated by the Cronbach's alpha value of the variables tested, which had an alpha for the standardised item that was greater than the allowable reliability value, which was 0.6. This means that the values of the statements in the questionnaire developed by the researcher and presented to respondents with different responses did not differ too much.

3 Results and Discussion

3.1 Physical and Chemical Parameters Distribution to Assessed Suitable Land for Cultivating Green Mussels

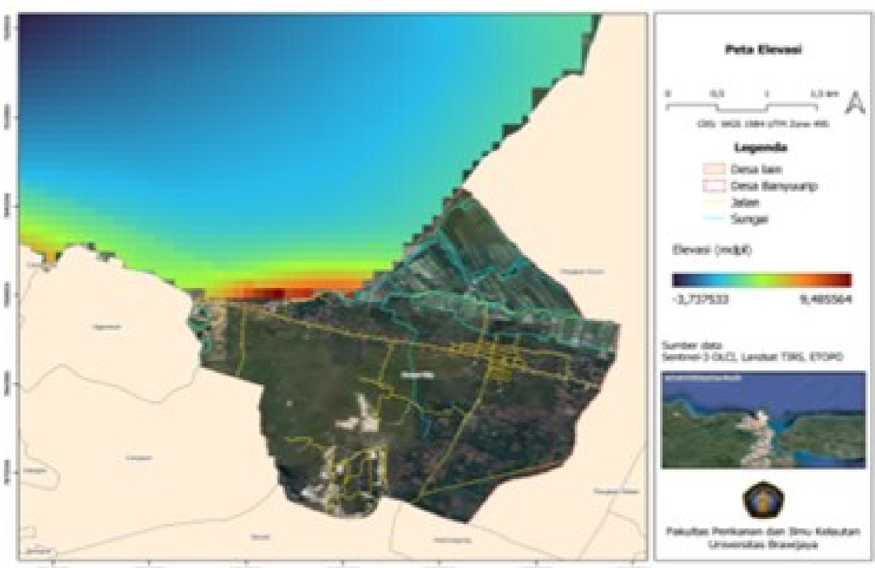

Fig. 4. Ocean depth map.

The GIS analysis produced a suitability map for green mussel aquaculture. Figure 4 is derived from the scoring of data on sea depth, sea surface temperature, chlorophyll a concentration and substrate radiance data. Before discussing the results, the four data were analysed. The Figure 5 shows the distribution of sea depth or elevation of the ocean area of Banyuurip Village. This data is resampled and not high-resolution sea depth data, so it looks like a homogeneous gradient. Nevertheless, this data provides a simple picture and values for depth rating. It is clear that the further an area of water is from the coast, the deeper it is, and vice versa.

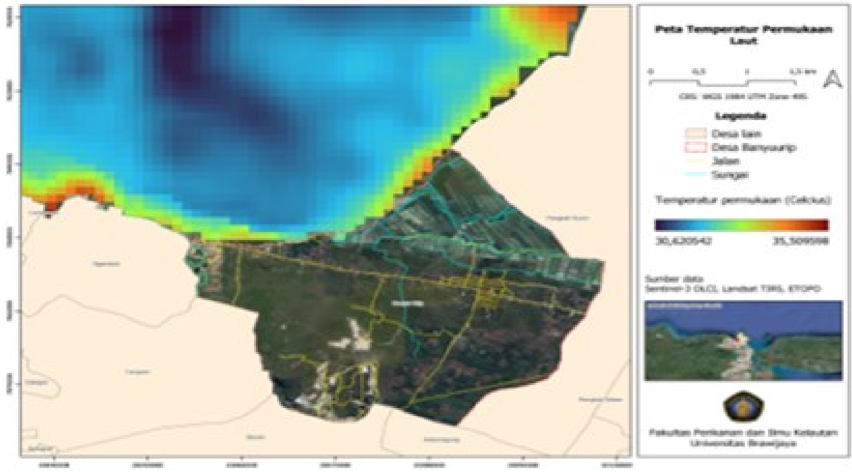

Fig. 5. Sea Surface temperature map.

Figure 5 shows the distribution of sea surface temperature along the coast near Banyu Urip Village. In general, it can be seen that the further an area of water is from the coast, the colder its surface is, and vice versa. This map also shows the potential for the cultivation of green mussels, which prefer warmer water, i.e. closer to the coast. Figure 6 shows the distribution of chlorophyll a. This map differs from the previous one in that the distribution of chlorophyll does not depend on the distance from the coast, but has its own clustering pattern.

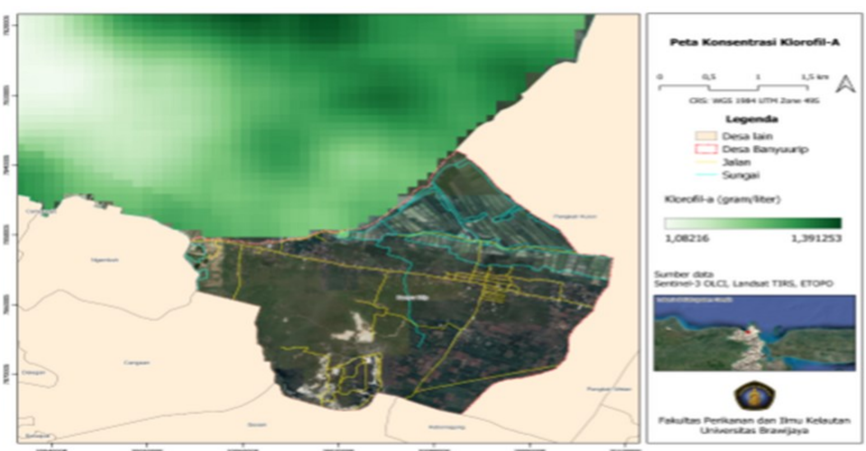

Fig. 6. Chlorophyll concentration map.

The dense chlorophyll is located in the north of the map, far from the coast, and also near the east coast. It is likely that this pattern is caused by the flow of river deltas, which carry a lot of chlorophyll to the north-west. Figure 6 is similar to the chlorophyll map in terms of cluster height. There is a lot of substrate in the north-west of the map, which is the outlet of the river drainage. However, this substrate also has a pattern of being high from the coast and decreasing as one moves northwards, except in the north-east, which is the outlet of the river drainage (Figure 7).

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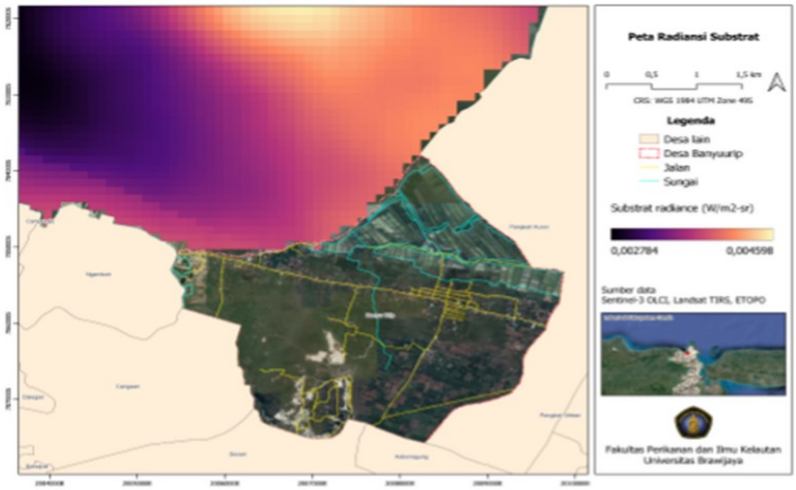

Fig. 7. Map of substrate radiance

Figure 8 is the final map obtained for the suitability category for green mussel cultivation. This map provides a combined pattern of the previous four maps. The coastal and northeastern areas have high suitability due to high chlorophyll and substrate. The north-western and north-central areas have low suitability due to lack of substrate and chlorophyll. Areas with warm temperatures and shallow depths still had high suitability score for mussel cultivation.

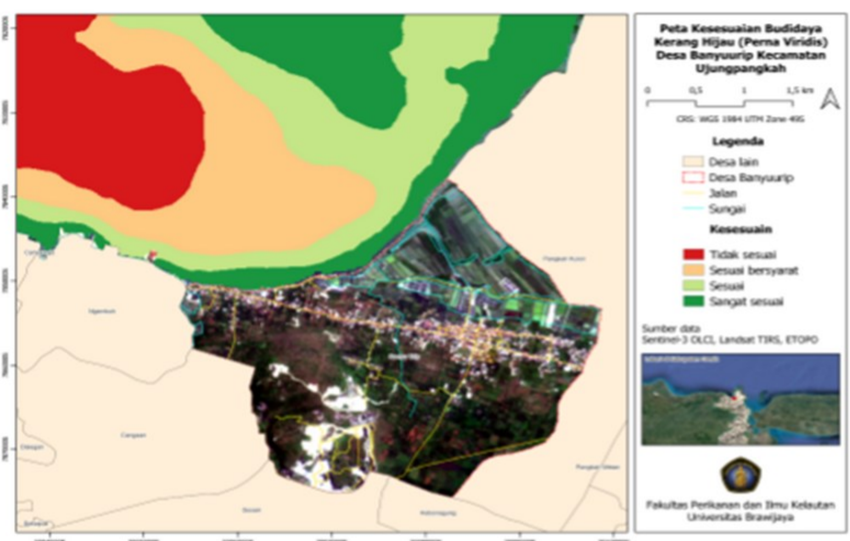

Fig. 8. Green mussel cultivation suitability map.

3.2 Green Mussels Sizing

Measurements of green mussel shell length and width were made by collecting green mussel shells in the waters of Banyuurip. Data were collected from station 1 to station 5, and as many as 20 samples of each green mussel were collected.

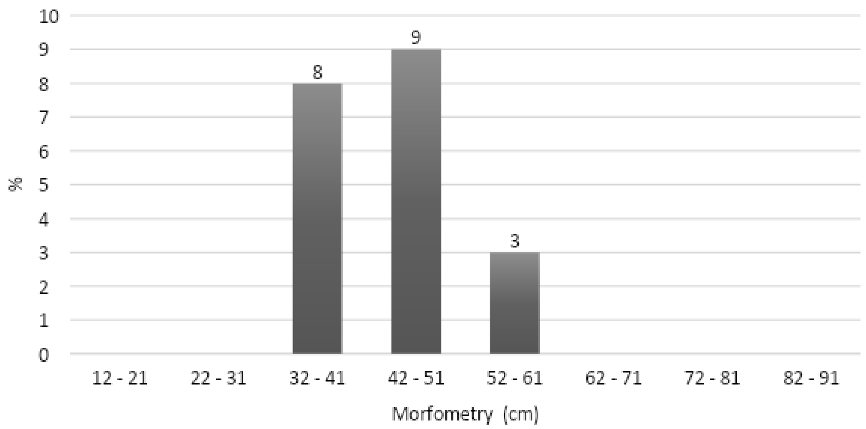

Fig. 9. Analysis of the size distribution of the green mussel length at station 1

Based on the results of the analysis of the size distribution of the green mussel length class at station 1, three classes of green mussel length were obtained: 32-41 cm; 42-51 cm; and 52-61 cm. The 32-41 cm length class had a percentage of 8%, the 42-51 cm length class had a percentage of 9% and the 52-41 cm length class had a percentage of 3%. The results of the distribution analysis of the length class size of green mussels at station 1 can be seen in Figure 9.

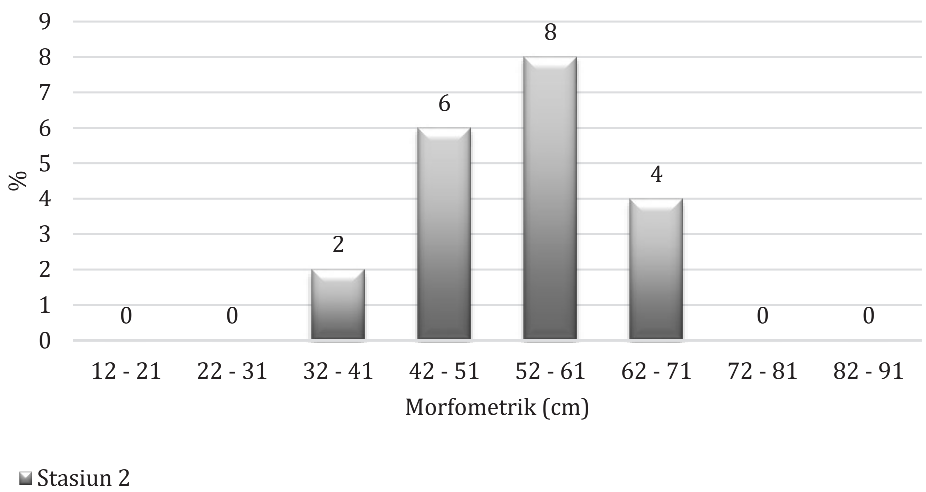

Fig. 10. Analysis of the Size Distribution of The Green Mussel Length at Station 2

Based on the results of the distribution analysis of the length class size of green mussels at station 2, four length classes of green mussel were obtained: 32-41 cm, 42-51 cm, 52-61 cm and 62-71 cm. The length class 32-41 cm had a percentage of 2%, the length class 42-51 cm had a percentage of 6%, the length class 52-41 cm had a percentage of 8% and the length class 62-71 cm had a percentage of 4%. The results of the distribution analysis of the length class size of green mussels at station 1 can be seen in Figure 10.

Based on the results of the analysis of the distribution of the length classes of green mussels at station 3, four classes of green mussel length were obtained: 12-21 cm; 32-41 cm; 42-51 cm; and 52-61 cm. The 12-21-cm length class size had a percentage of 1%, the 32-41-

cm length class had a percentage of 10%, the 42-51-cm length class had a percentage of 8% and the 52-61-cm length class had a percentage of 1%. The results of the analysis of the distribution of green mussel length classes at station 1 are shown in Figure 11.

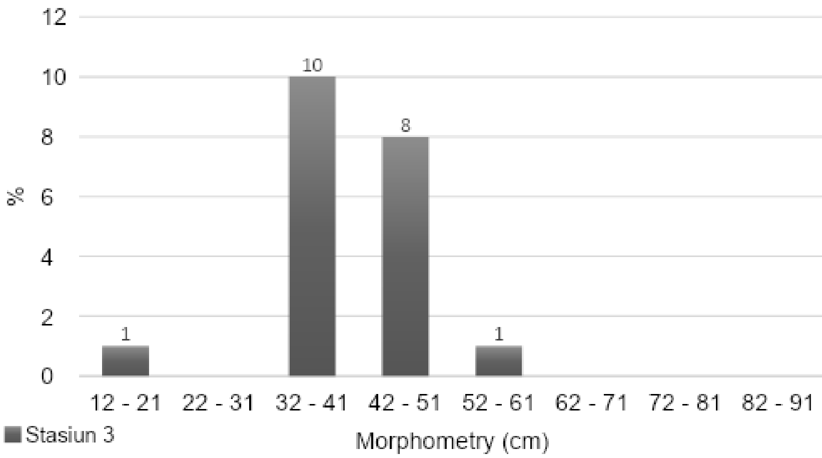

Fig. 11. Analysis of the size distribution of the green mussel length at station 3.

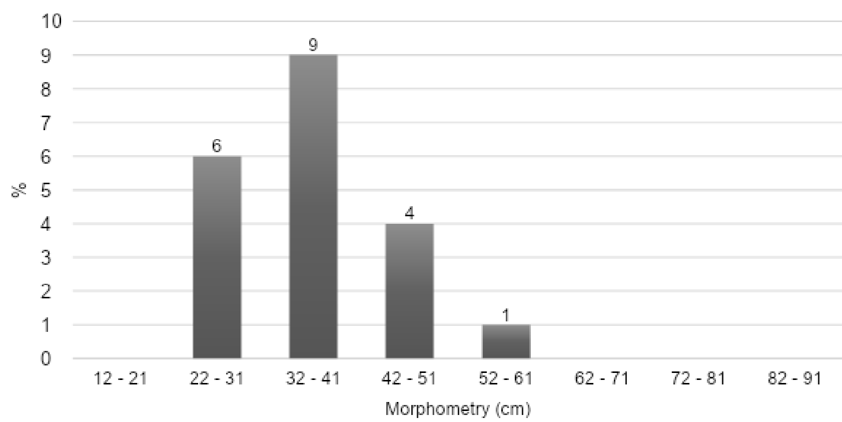

Fig. 12. Percentage of green mussel length size classes at station 4.

Based on the results of the analysis of the distribution of length size classes of green mussels at station 4, four classes of green mussel length were obtained: 22-31 cm; 32-41 cm; 42-51 cm; and 52-61 cm. The 22-31 cm length size class had a percentage of 6%, the 32-41 cm length size class had a percentage of 9%, the 42-51 cm length size class had a percentage of 4% and the 52-61 cm length size class had a percentage of 1%. The results of the distribution of the analysis of length size classes of green mussels at station 1 can be seen in Figure 12.

Based on the results of the analysis of the distribution of length size classes of green mussels at station 4, six length classes of green mussels were obtained: 22–31 cm; 32-41 cm; 42-51 cm; 52-61 cm; 62-71 cm; and 82-91 cm. The 22-31 cm length class had a percentage of 2%, the 32-41 cm length class had a percentage of 6%, the 42-51 cm length class had a percentage of 6% and the 52-61 cm length class had a percentage of 2%. Meanwhile, the 62-71 cm length class had a percentage of 3% and the 82-91 cm length class had a percentage of 1%. The results of the analysis of the distribution of length size classes of green mussels at station 1 are shown in Figure 13.

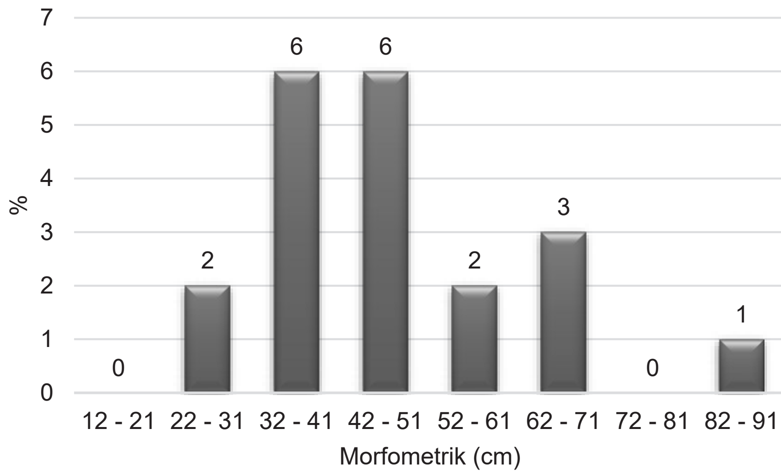

Fig.13. Percentage of green mussel length size classes at station 5.

3.3 Shell Thickness Index

Table 2. Shell thickness index

Stations	St Dev population			Results	Average			Results	IST
	Length	Width	Height		Length	Width	Height		
1	0.69469	0.31917	0.14924	0.03309	4.32	2.075	1.515	13.5804	0.24%
2	0.89603	0.30475	0.23216	0.06339	5.325	2.625	1.71	23.9025	0.27%
3	0.83821	0.20469	0.21277	0.03650	3.98	1.89	1.285	9.66602	0.38%
4	0.782368	0.32752	0.17635	0.04519	3.57	1.735	1.17	7.24692	0.62%
5	1.38019	0.52086	0.39430	0.28346	4.8445	2.3005	1.455	16.2156	1.75%

The shell thickness index (STI) can be used to assess the healthiness of green mussels, with slender and elongated mussels being healthier than those with rounded shells. The higher the shell roundness index value, the rounder the shell will be. High levels of water pollution can cause deformation or malformation of the shell [20]. The shell roundness index value of green mussels in Banyuurip had a higher value than those in the research conducted by [20] in Makassar, with a shell roundness index value of 0.12%. This shows that green mussels in Banyuurip were less healthy than the green mussels in Makassar.

Furthermore, the relationship between the shell roundness index regression test and the Pb content of *Perna viridis* can be seen in the graph on Figure 14. The graph of the relationship between Pb content and Shell Roundness Index above shows that the linear correlation value was 0.207, which means that the relationship between the two was low. A coefficient of determination of 0.04% was also obtained, indicating that the shell roundness index influenced the Pb content in green mussels by 0.04% and the rest was influenced by other factors (Figure 14). The results of the analysis showed a significance value of 0.737 > $\alpha = 0.05$, indicating that there was no significant influence between the shell roundness index and the Pb content in green mussels. This is supported by the research conducted by [21], where the correlation between shell roundness morphometry and the level of metal content in the shell was weak.

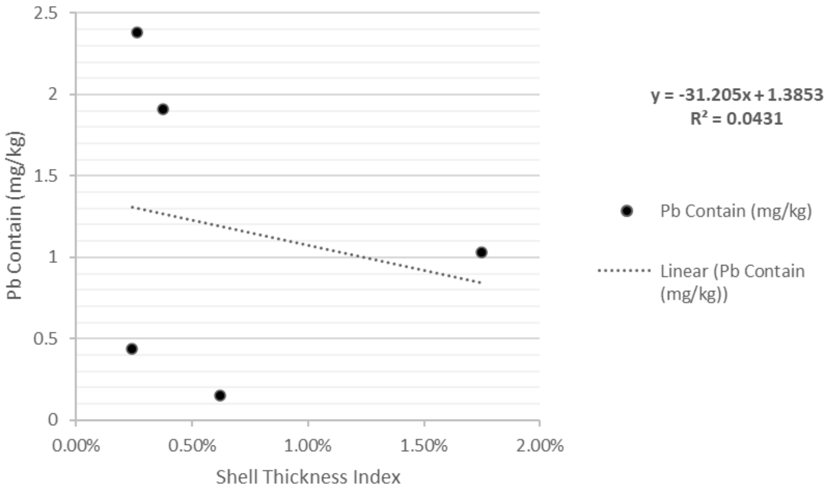

Fig. 14. Graph of the relationship between shell thickness index and pb content.

3.4 Grain Size and Sediment Type

Based on the results of sediment texture analysis in the waters of Banyuurip Village can be seen in Figure 15 The size of the fraction at each station was in the range of 5.98%-13.47% in the sand fraction, 72.44%-80.15% in the silt fraction and 13.87%-14.85% the clay fraction. The highest fraction value at each station is in the silt category and the lowest in the sand category. The type of sediment obtained from Shepard's triangle analysis at each station was entirely silt loam or dusty clay. This type of sediment is a small grain size sediment with a fine texture. Current is one of the factors that will affect sedimentation and the grain size distribution of the sediment deposited. Waters with strong currents are characterised by a coarse sediment distribution as fine particles are stirred up in the water column and distributed elsewhere [22]. The current conditions in the waters of Banyuurip Village are relatively calm, dominated by fine-grained silt loam sediments. According to [22], low current velocities support the easy deposition of heavy metal cations (Pb+2) in sediments, especially clay and silt. This is because fine sediment particles have a larger surface area with a more stable ion density to bind metals than larger sediment particles. Sediments with fine fractions and a lot of organic matter will have a higher heavy metal (Pb) content than those with coarser or larger fractions [23].

The discovery of heavy metal (pb) levels in green mussel meat in the waters of Banyuurip Village, which exceed the threshold set by the Indonesian Agency for Drug and Food Control (BPOM) and international standards, is probably due to its location near to the mouth of the Bengawan Solo river. The river is one of the sources of various organic, inorganic and heavy metal wastes entering the sea. In addition, these waters are close to the Gresik industrial area. However, there was one station where the Pb content in green mussel meat was still within the threshold range, namely station 4 with 0.15 mg/kg. The presence of heavy metals in green mussel meat is due to the fact that green mussels are filter-feeding organisms that filter food from particles carried in the water (Liliandari et al, 2013). Fine-particle sediments are easily stirred in the water column and bind heavy metals (Pb), so that these particles are absorbed by the filter-feeding green mussels and eventually accumulate in the body or meat of the green mussels.

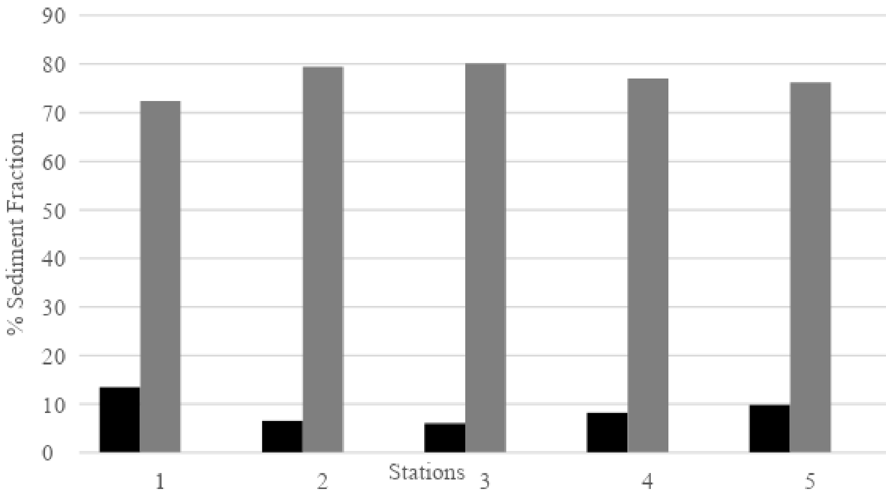

Fig. 15. Graph of Grain Size Distribution and Sediment Type.

3.5 PLS Modelling

PLS analysis produces a structural model that examines variables of community perception and behavior. The relationship between variables will be shown by a model as depicted in the Figure 16.

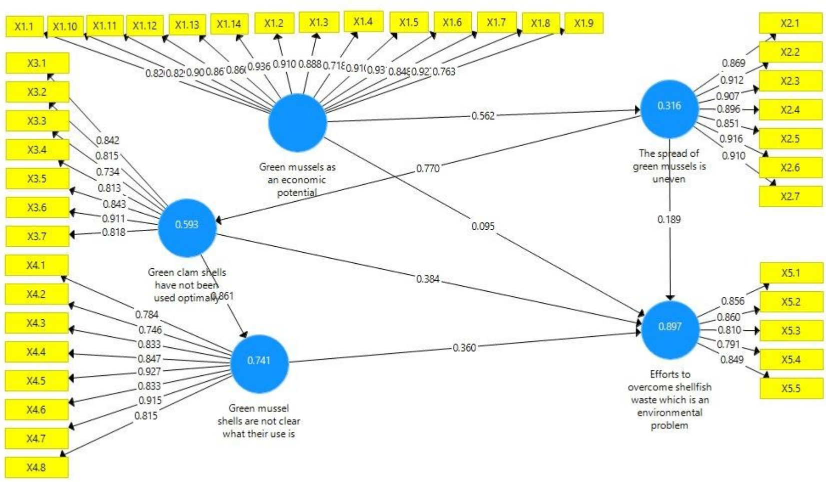

Fig. 16. Structural modelling of PLS.

Table 3. Objectives and variables for PLS modelling

Objectives	Variables
Green Mussels as a Potential Economic Resource	X1.1. The community sees the green mussels as a benefit to them and the other surrounding communities; X1.2. The community has agreed to repair the green shell mounds , so that Banyu Urip village can once again have a beautiful and comfortable beach atmosphere; X1.3. The community hopes that the green mussels will become an icon for the

Objectives	Variables
	Banyuurip community. X1.4. The community hopes that the village government will have a clear programme to promote the potential of green mussels as a community livelihood. X1.5. The community hopes that green mussels can be promoted as a source of food, traditional medicine, and also decorative materials; X1.6. The community hopes that green mussels will be free from water pollution, especially from oil spills X1.7. The community hopes that the government will them with the increasing cost of bamboo used for green mussels; X1.8. The community is facing problems in marketing green mussels; X1.9. The people of Banyuurip village work as green mussel farmers and fishermen; X1.10. Climate change is an important factor in the decline of green mussels; X1.11. The habitats of green mussels in Banyuurip Village include: estuaries, estuarine beaches, sandy beaches, rocky shores, coral reefs, seagrass beds, lakes, rivers, and mangroves; X1.12. Green mussel cultivation in Banyuurip Village is a sideline business for the community as the cultivation technique is simple. The business does not require much capital and the mussels can be harvested after 6 to 7 months; X1.13. The yield of green mussels per hectare per year can reach 200 to 300 tonnes of whole mussels or about 60 to 100 tonnes of mussel meat; X1.14. Green mussels are abundant from March to July in intertidal and subtidal areas. They live in clusters and cling strongly to their byssus threads, such as wood, bamboo, rocks or hard substrates.
Uneven distribution of green mussels	X2.1. The community considers green mussels are currently in short supply; X2.2. The community believes that the distribution of green mussels is influenced by whether the water is polluted or not; X2.3. The community assumes that green mussels are unevenly distributed in the coastal waters; X2.4. The community assumes that the presence of green mussels is determined by the temperature of the water. The hotter the water is, the fewer green mussels there will be; X2.5. The community assumes that the role of the green mussel is as an indicator of whether the aquatic environment is good or bad; X2.6. The community assumes that green mussels have limited movements and are relatively sedentary in an area; X2.7. The community assumes that changes in the polluted aquatic environment will affect the life of green mussels;
Green mussel shells that have not yet been fully utilised	X3.1. People think that the utilisation of green mussel shell waste as a substitute for cement has not been done optimally; X3.2. The community hopes to overcome flooding together with the local government and the private sector. They believe that green mussel shells can be used as a substitute for normal concrete mix; X3.3. The community hopes that the village government will find a solution for the flooding as soon as possible to prevent abrasion, erosion and sedimentation in the coastal areas. They believe that the burning temperature of the green mussel shells will provide optimum concrete strength; X3.4. The community expects that unused green mussel shells will generate an increasing amount of waste; X3.5.The community considers that there is a lack of utilisation of shell waste, which is currently used only as decoration, animal feed, food source and cosmetic ingredient; X3.6. It is believed that green mussel shells have a high calcium content; X3.7. The community considers that the presence of green mussel shells is

Objectives	**Variables**
	increasingly disturbing the environment of the fishing village and damaging the beauty of the beach;
Uncertain utilisation of green mussel shells	X4.1. People think that the solid waste of green mussel shells is only used for the meat/muscle, while the shells are discarded and become waste; X4. into waste; X4.2. The community thinks that the processing of green mussel shells should be more optimised and environmentally friendly; X4.3. People think that the utilisation of green mussel shells should reduce the negative impact on human health the environment; X4.4. People think that the potential of green mussel shells as a high source of calcium is high. X4.5. The community believes that green mussel shell waste contains high levels of calcium carbonate and has the potential to be utilised; X4.6. The community believes that the demand for green mussels will increase and that green mussel farming will be intensified; X4.7. Nutritional content of green mussel shells can be exploited and utilised to improve product quality; X4.8. People think that green mussel shell waste can be utilised as high calcium powder;
Efforts to manage green mussel waste that becomes a source of environmental problems	X5.1. Green mussels are believed to be an inexpensive source of animal protein and a good source of essential amino acids; X5.2. People think that green mussels contain about 30% meat by weight; X5.3. People think that the utilisation of green mussel shell waste is to reduce the negative impact of shell waste; X5.4. People assume that green mussels can maintain bone density and tooth formation because they contain calcium, which can build bones; X5.5. People think that as the depth of the beach increases, the penetration of sunlight into the water decreases, which is a limiting factor for vertical distribution.

The variables presented in Table 3 each have a different number of instrument items developed by the researchers, and all instrument items met the validity test requirements as each had a significance value (p) less than alpha 0.05. Thus, all instrument items from all observed variables were included in further testing. As for the reliability coefficient when calculating the formula, it was then interpreted, based on the reliability criteria proposed by [24], that the reliability criteria for group achievement is considered adequate if the alpha coefficient is 0.60-0.70. The reliability coefficient index criteria can be seen in the following Table 4.

The Table 4 explains that all the items were reliable as measures of the variables observed, since the Cronbach's alpha value of the variables tested had a standardised item alpha greater than the allowable reliability value, which is 0.6. Despite the differences in the statements on the questionnaire developed and submitted to respondents, the responses of the respondents were not too different.

The graph of the relationship between Pb content and shell roundness index shows a linear correlation value of 0.207 (Table 5), which means that the relationship between the two was low. A coefficient of determination of 0.04% was also obtained, indicating that the shell roundness index influenced the Pb content of the green mussels by 0.04% and the rest was influenced by other factors. The results of the analysis showed a significance value of 0.737 $> \alpha = 0.05$, indicating that there was no significant influence between the shell roundness index and the Pb content in green mussels. This is supported by the research conducted by [21], where the correlation between shell roundness morphometry and the level of metal content in the shell showed a weak correlation.

Table 4. Reliability testing of research instruments

Variables	**Cronbach's Alpha** (*based on standardised items*)	**Remarks**
Green mussels as a potential economic resource	0.974	Reliable
Green mussel shells that have not been optimally utilised	0.957	Reliable
Green mussel shells have no clear use	0.922	Reliable
Green mussel shells have no clear use	0.939	Reliable
Efforts to manage shell waste that becomes an environmental problem	0.890	Reliable

ANOVA for *Perna viridis* morphometrics at each station was performed to test for differences between groups. The appropriate data type for ANOVA is nominal and ordinal in the independent variable when the data in the independent variable is in the form of an interval or ratio.

Table 5: ANOVA for Morphometrics

Source of Variance (SK)	Sum of Squares (JK)	Free Degree (db)	Centre Square (KT)	F_{test}	P-Value	F_{table} 5%	F_{table} 1%	
Stations	2.05178	4	0.51294	7.62369	0.00777	3.83785	7.00607	**
Morfometry	24.3071	2	12.1535	180.633	2.2E-0	4.45897	8.64911	**
Error	0.53826	8	0.06728	-	-	-	-	

If F_{test} is > F_{table} 5% and < F_{table} 1%, the effect is significant; if F_{test} is > F_{table} 1%, the effect is very significant.
ns: "not significant" or not real
*: significant effect at the %% level
** very significant effect at the 1% level

4 Conclusion

At the end of the discussion, it was concluded that it is important to have information on the distribution of *Perna viridis* habitats in a water body as a basis for management. For this reason, the distribution analysis of the green mussel is a tool to identify areas with *Perna viridis* habitats that are worth managing and optimising their use, and areas that need to be conserved. Regional differences are based on hydroceanographic patterns and the accumulation of pollutants entering the water. The results of substrate/sediment and heavy metal measurements show that the heavy metal content of Pb is located and distributed in polluted areas. The results of the analysis of community behaviour and perceptions show that until now the community is not yet aware of the quality of waters that are suitable for growing green mussels. People still think that any water can be a good place to grow green mussels, whereas in fact the water has an impact on the yield of mussels and therefore on the income generated from them. The biggest threat in the Widoro Bay area is tidal flooding and in order to adapt, a joint effort is needed from both the local government and the community to work together to build a natural fortress through the restoration of mangrove forests. Therefore, mapping through a spatial approach shows that the distribution of Perna viridis in banyuurip waters is evenly distributed. This is supported by water quality parameters that are in accordance with their habitat. Observation results from spatial data show that perna viridis cultivation uses bamboo poles with an average length of $\pm$ 14 meters. Based on spatial maps of seawater depth, temperature distribution, chlorophyll, substrate, and aquaculture suitability maps show that banyuurip waters are very potential for perna viridis life. An Analysis of community perceptions and behavior based on PLS results shows that the Banyuurip community really hopes that Perna viridis cultivation can continue to be improved by expecting that Perna viridis shells can be managed properly. This is because green mussel shell waste has a negative impact on the environment. Fishing communities that utilize Perna viridis expect the local government to cultivate green mussel shell waste more proportionally. The results of distribution analysis shows that: a) The distribution of Perna viridis in the Banyuurip area is evenly distributed. This is evidenced by the support of adequate water quality for Perna viridis habitat. The distribution of Perna viridis allows fishermen to utilize aquatic habitats that are suitable for the life of Perna viridis; b). Laboratory analysis results show that the heavy metal content of Pb in Perna viridis is harmful to health. This is because the average Pb content in Perna viridis is still above the threshold except at station 4 with a value of 0.2 mg/kg. However, referring to the average international standard shows that the threshold of Pb content in Perna viridis that can be consumed is above 2 mg/kg.c) Based on the shell roundness index, the Banyuurip waters were categorized as not heavily polluted.

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