Ecobiology of Asian-moon Scallop *Amusium pleuronectes* (Linnaeus, 1758) in Kendal Regency Coast, Central Java

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Abstract

Asian moon scallops are one of the marine biological resource products that have the potential to be utilized optimally and in national and international trade and have high economic value. Kendal waters are one of the districts with significant *Amusium pleuronectes* resource potential to meet export needs in Indonesia, apart from the waters of Brebes, Tegal, Pemalang, Pekalongan, and Batang regencies. This research aims descriptively to explain the habitat characteristics of *A. pleuronectes* by connecting the condition of the relationship between body size and weight of *A. pleuronectes* and the parameters quality of the waters where the scallops are located, based on fishermen's fishing ground routes. *A. pleuronectes* was sampled using a fishing boat with a traditional *arad* net. The Global Positioning System (GPS) would be turned on when the *arad* net was finished being lifted, and the coordinates were recorded. The sampling stations were determined as 4 points, spread randomly (purposive sampling) along the route of fishermen catching *A. pleuronectes*. At the same time, water, sediment, and water parameter sampling was carried out. The samples were then taken to the laboratory for biometric measurements to determine the condition of the *A. pleuronectes*. Water samples were tested for chlorophyll-a and nitrate content, while sediment was tested for grain size and organic matter content. A Principal Component Analysis (PCA) analysis was conducted to determine the relationship between biometric parameters and water parameters. The results of this study showed that the scallops have a relationship between size and weight $x<3$, so they have negative allometry. These scallops have an average condition index of 51.12 and are in the medium category. In the preliminary survey, these scallops were dominated by the 4.1-5 cm size class. At stations 1-3, the size class 6.1-7 cm is dominated. *A. pleuronectes* were not found at station 4. These scallops showed a close relationship with salinity, depth, nitrate content, and silt substrate, with a higher content of coarse sand and clay as a substrate. There is little relation to organic matter, chlorophyll-a, temperature, dissolved oxygen, pH, gravel substrate, silt, and fine sand.

Keywords: Asian Moon Scallop, Biometry, habitat, index condition, Principal Component Analysis

INTRODUCTION

Asian moon scallops, *simping* in the local name (*Amusium pleuronectes*), are one of the economically valuable fishery resource products. This species mostly lives in water areas protected from large ocean waves and currents, such as East Java's and Central Java's northern coast. On the North coast of Central Java, the waters of Kendal Regency are one of the regencies that have the potential to produce *A. pleuronectes* to meet export needs in Indonesia apart from the waters of Brebes Regency, Tegal Regency, Pemalang Regency, Pekalongan Regency and Batang Regency (Prasetya *et al*. 2010).

During the production season, the average annual production of scallops in 2017-2021 nationally is 679 tons. The production value of *A. pleuronectes* in Central Java is 202 tons per year from various processed shellfish (KKP 2022). The distribution of *A. pleuronectes* is influenced by several environmental factors, such as temperature, salinity, and substrate. Temperature has a significant role in scallop's activity. According to Widowati *et al*. (2008), *A. pleuronectes* were caught in Brebes waters in May, and the water temperature ranged between 28 and 29 °C. The salinity in Pekalongan waters of *A. pleuronectes* scallops was around 29-39 ppt (Widowati *et al*., 1999). Salinity is influenced

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by weather changes; when rainfall is low, salinity will be high, and *vice versa*. Low salinity is due to weather changes, which will increase scallop mortality (Shumway & Parsons, 2006).

Potential areas for *A. pleuronectes* scallops' habitat can be identified if the bioecological conditions of the shellfish are known. Good scallops' condition will determine the optimal level of shellfish health. Several studies have been conducted on the condition of shellfish and the bioecology of *A. pleuronectes* on the North Coast of Central Java, including in the waters of Brebes Regency (Sahri *et al*. 2014; Taufani *et al*. 2016), Pemalang Waters (Febrianto *et al*. 2013; Ratnaputri *et al*. 2013) and in Semarang and Kendal waters (Nursalim *et al*., 2012). Research on the condition of shellfish in Kendal Regency was carried out by Nursalim *et al*. (2012) with results showing *b* values of 3.070, 2.853, and 2.862, and negative isometric and allometric for sampling one, two, and three. *Simping* population with a relative growth rate model of 1 cm for shell length, 0.5 cm for shell height, 0.2 cm for shell thickness, and 5 grams for total shell weight. The condition index value of *simping* (*A. pleuronectes*) ranged from 36.01% - 61.44%. This research aims to gain further knowledge regarding the bioecological characteristics of *A. pleuronectes* so that initial studies can be conducted to assess potential areas for these scallops in Kendal waters.

MATERIALS AND METHODS

A preliminary survey was carried out in November 2023 in Kendal waters, and *A. pleuronectes* were collected by purchasing directly from the fishermen. The sampling was done in December 2023. Scallops were caught using traditional *arad* nets with a length of 45 meters and an opening of 5 meters. The fishermen's boat used a motor boat with a size of 9 M × 3.6 M and a speed of 3 knots. Each of the four station's boat trips was sampled and the average towing time was 1-2 hours. The distance from the coastline is 18 km, and each station is marked using a Garmin 60 Csx GPS.

A. pleuronectes scallop samples were sorted from other catches and separated at each station. Water quality data was collected: depth, temperature, pH, salinity, dissolved oxygen, chlorophyll-a, organic matter, nitrate. Water samples were taken using a Nansen bottle, and sediment samples were taken using a Sediment Grab. The samples were then put into a coolbox containing ice and taken to the Laboratory of Marine Biology, Faculty of Fisheries and Marine Science, Universitas Diponegoro, for biometry measurements.

Analysis of the length-weight relationship includes measuring the dimensions of the *A. pleuronectes* shell and weighing the shell. Both total weight and tissue weight were noted. To determine the relationship between growth and shell dimensions and body weight of scallops, the regression equation formula is used according to Ricker (1975):

$$Y=aX^b$$

Where W = wet weight of shellfish (g), X = one of the dimensions (length, width, height (cm), a and b are constants in the equation.

The criterion for scallop growth is to use the relationship between weight and length, depending on the *b* value' which is the allometric coefficient, to reflect relative growth. If the value of $b = 3$, then the growth is called isometry, where the growth in shell dimensions is the same proportion as the growth in total weight. Meanwhile, if the value of $b < 3$ (negative allometry), the growth in length is faster than the growth in weight, or if $b > 3$ (positive allometry), the increase in weight is faster than the increase in length. The growth in shell dimensions is not the same proportion as the growth in total weight.

The condition index of scallops (*Amusium pleuronectes*) is calculated using the formula:

$$Condition\ index\ (\%) = \frac{soft\ tissue\ weight}{total\ weight} X100$$

The condition index value categories, according to Davenport and Chen (1987), is as follows : A condition index value of less than 40 is the thin category; A condition index value between 40-60 is the medium category; A condition index value of more than 60 is in the obese category.

Principal Component Analysis (PCA) uses the Euclidean distance index on the data. The Euclidean distance relationship is based on the formula:

$$D^2\ (i,\ i') = \Sigma\ (Xij - Xi'j)^2$$

Where i, i are two stations (on the line) and j are environmental parameters. The smaller the Euclidean distance between two stations, the more similar the bio-physiochemical characteristics between them, and vice versa. PCA calculations were carried out using the XLSTAT statistical program package (Nugroho *et al*. 2019).

RESULTS AND DISCUSSION

This research has collected 116 samples of *A. pleuronectes* in the preliminary survey. During field data collection, 80 individuals were found at station 1, 64 individuals at station 2, 13 individuals at station 3, and no samples were found at station 4. The difference in the number of samples is likely due to differences in water depth. The relationship between the shell dimensions (length, width, height) of *A. pleuronectes* shells and the weight of scallops obtained from Kendal waters showed negative allometric results with constant values at the time of the preliminary survey and at each station with a value of $b<3$.

The results of the comparison of growth characteristic values, seen in the preliminary survey and during field research at stations 1, 2, and 3, *A. pleuronectes* shellfish in the waters of Kendal Regency showed a negative allometric length-weight relationship where the growth of shellfish was faster than the growth of shell weight. This is because, in the early life cycle of the scallops, *A. pleuronectes* tends to prioritize survival. This condition is related to the environment where the scallop's habitat of *A. pleuronectes* is located, namely in waters that tend to be profound. The presence of *A. pleuronectes* in November and December 2023 shows these scallops are in the growth phase. In this phase, shell formation will generally be prioritized; the surface area of the scallop shell can protect all the tissue that will form in the next phase. This is following research by Widowati *et al*. (2008), that the scallops *A. pleuronectes*, which was found in the waters of Brebes Regency in 2008, obtained observation results using the linear regression method and obtained negative allometric growth characteristics with an allometric coefficient value of b = 0.878. It was further explained that the faster growth in shell length was due to the shellfish *A. pleuronectes* being in the growth phase. This is supported by the abundant natural food stock of *A. pleuronectes* shellfish. Meanwhile, weight growth tends to be slow because these scallops have not yet entered the reproductive phase and are still concentrating on shell growth. In this way, the negative allometric form illustrates the length-weight relationship obtained, which is the planning of the *A. pleuronectes* shellfish in preparation for the reproductive and development stages (Zulfahmi *et al*. 2021).

The results of the calculation of the *A. pleuronectes* shellfish condition index are shown in Table 2. Based on data from Table 2, samples of *A. pleuronectes* obtained in the waters of Kendal Regency had an average condition index value in the preliminary survey of 46.22. When the field research was carried out, the average condition indices at stations 1, 2, 3, and 4 were as follows: 51.91, 54.83, 53, and 10. Meanwhile, the condition index values are grouped into three categories: category 1, or thin category; category 2, or medium category; and category 3, or fat category, according to Davenport and Chen (1987). The average minimum condition index is 41.13, the average value of the condition index is 51.54, and the average value of the maximum condition index is 64.34.

These condition index values have shown that the growth of *A. pleuronectes* scallops is closely related to environmental conditions and the breeding phase. This is because when the *A.*

pleuronectes enters the gonad development stage, it will be directly proportional to the increase in the condition index value. Suprijanto *et al*. (2007) showed a similar result, where *A. pleuronectes* had mature gonads and had gone through the reproductive period, and they had a condition index that tended to be more significant. *Vice versa*, if the condition index is low, the scallops have not gone through the reproductive phase and are not yet at the mature gonad phase. The results of water parameters measurements such as temperature, salinity, DO, pH, amount of chlorophyll-a, nitrate content, depth, and organic matter content in the sediment are shown in Figure 1.

The Field measurement results show that the water temperature is in the range of 30-33°C. According to Shumway (2006), the development level of *A. pleuronectes*' maturity is influenced by temperature. These shellfish can grow optimally in the ocean at 24.5-33°C (Dharmaraj *et al*. 2004). The salinity values obtained ranged from 29-33 ‰. Salinity has an essential role in the life of organisms, for example, in the distribution of aquatic biota. Salinity is one factor that plays a role in the marine ecological environment. According to Dharmaraj *et al*. (2004), suitable salinity is necessary for developing *A. pleuronectes* shellfish in the 18-38 ‰ range.

Table 1. Relationship between dimensions and the total weight of *A. pleuronectes* in Kendal coastal

Station	N	Linear equations	regression	Note
Preliminary survey				
Length	116	Y= 0,2629x-2,3024	0,9655	Allometric Negative
width	116	Y = 0,3308x-2,1738	0,898	Allometric Negative
Height	116	Y = 10,941x-1,2486	0,8894	Allometric Negative
Station 1				
Length	80	Y = 0,1333x-2,6406	0,8289	Allometric Negative
Width	80	Y = 0,1488x-2,6088	0,8531	Allometric Negative
Height	80	Y = 11,031x-2,3032	0,8848	Allometric Negative
Station 2				
Length	64	Y = 0,0812x-2,8867	0,9249	Allometric Negative
Width	64	Y = 0,1391x-2,6169	0,8824	Allometric Negative
Height	64	Y = 10,796x-2,1013	0,7977	Allometric Negative
Station 3				
Length	13	Y = 0,442x-1,9537	0,5733	Allometric Negative
Width	13	Y = 0,4069x-2,0212	0,6437	Allometric Negative
Height	13	Y = 13,893x-0,4231	0,0471	Allometric Negative

Table 2. Condition Index of *A. pleuronectes* shells

Condition Index							
Trip	Station	N	Average	STDEV	Max	Med	Min
1	-	116	46,22	5,41	65,29	44,99	35,04
2	1	80	51,91	5,29	64,60	52,40	39,59
2	2	64	54,83	4,13	63,41	54,77	46,47
2	3	13	53,10	5,74	64,05	54	43,42
Average		68	51,52	5,14	64,34	51,54	41,13

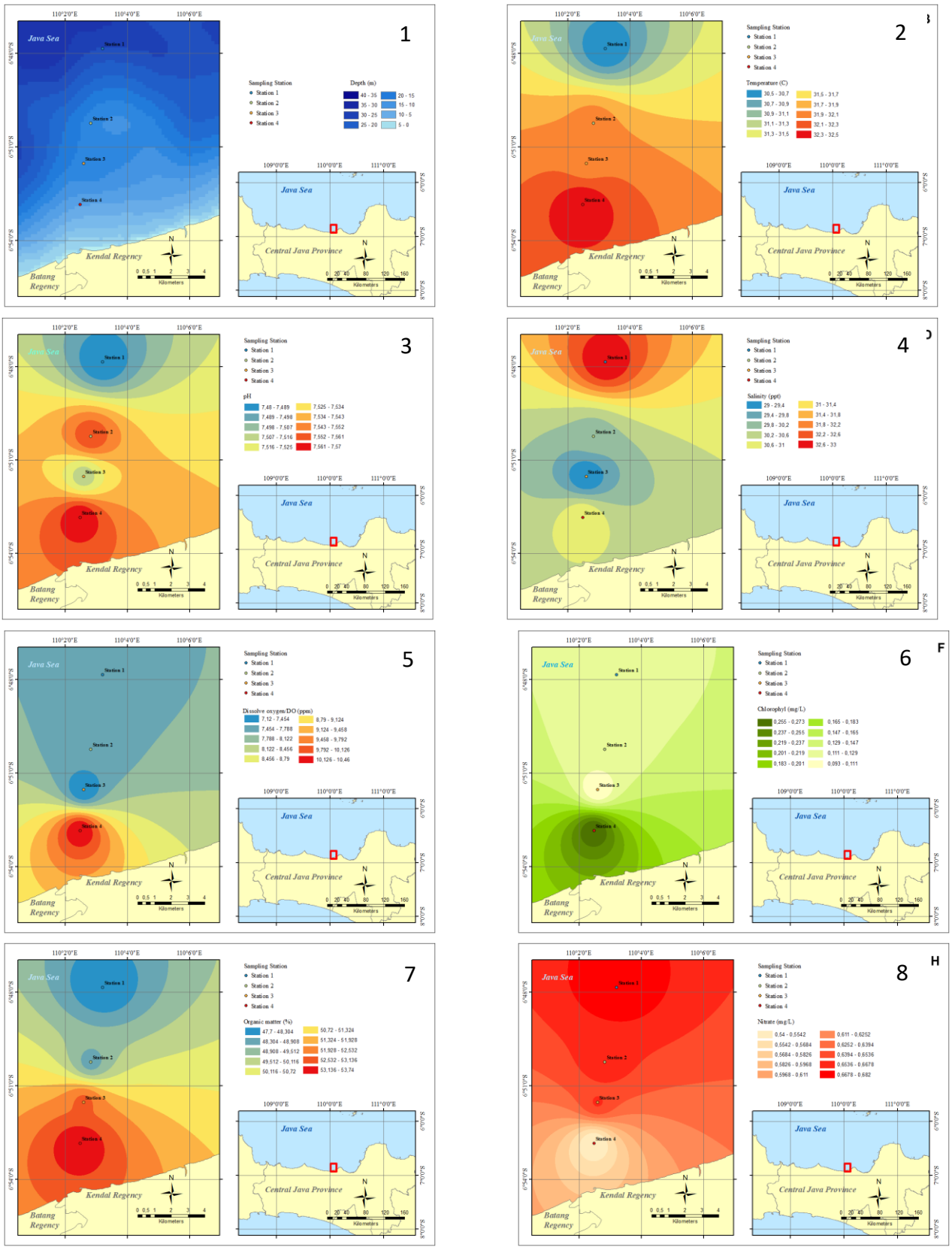

Figure 1. Spatial Distribution Map of Water Conditions: (1) Depth; (2) Temperature; (3) pH; (4) Salinity; (5) Dissolved Oxygen; (6) Chlorophyll-a; (7) Organic Matter; (8) Nitrate

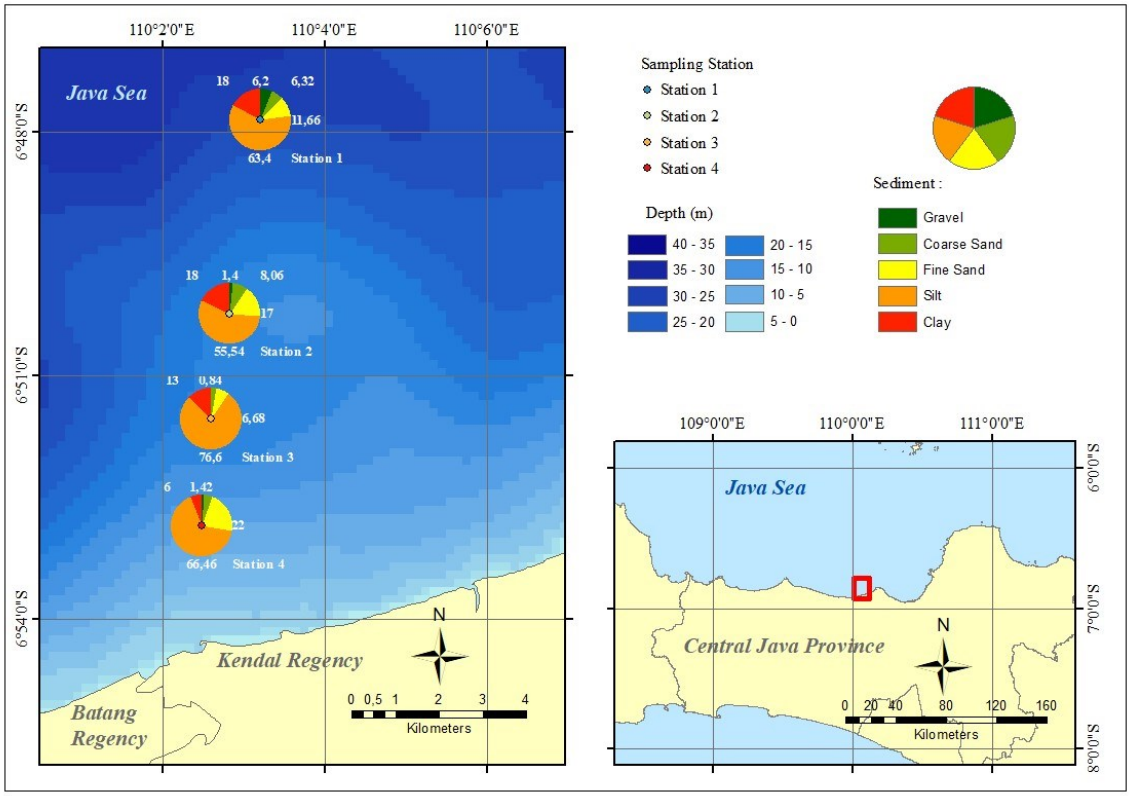

Figure 2. Sediment grain size at the research location

The dissolved oxygen value obtained in the field was between 7.12 and 10.46 mg.L^{-1}. The dissolved oxygen content in the waters of Kendal Regency is optimal, considering that the minimum level marine biota can tolerate is 4 mg.L^{-1}. Dissolved oxygen levels at station 4 are greater, possibly due to the proximity to land, the source from which the estuary and open sea meet. The pH values obtained are similar, ranging between 7.48-7.57. The pH value will affect the shellfish spawning process. Mussels will spawn quickly when in alkaline conditions and tend to be slower when conditions are acidic (Bahtiar, 2005). According to Effendi (2003), most benthic biota are sensitive to changes in pH and tend to prefer a pH between 7-8.5. Nutrients are essential in influencing the availability of food sources for *A. pleuronectes*. In this case, the function of nitrate is to form photoplasm in the photosynthesis process. The nitrate value in this study showed little effect on the amount of chlorophyll-a in the water-organic matter results from animals and plants that have decomposed in waters and mixed with the substrate. Organic matter is one of the food sources of benthic animals (Day, 1999). The organic matter content in this study was in the range of 47.7-53.74 %. In this study, the depth was in the range of 8-32 m. This depth affects the distribution of scallops. According to Bahtiar (2005), increasing depth influences food availability. This creates a barrier for plankton to become food for young shellfish, so many shellfish are near the surface.

The results of measuring the sediment grains are shown in Figure 2. Samples were taken at a depth of 8-32 m. The size of the sediment grains showed that the substrate condition was dominated by the silt fraction, followed by the clay fraction at stations 1, 2, and 3, and the fine sand fraction at station 4. Figure 3 shows the results of the correlation between water quality variables shown on the F1×F2 axes using the main analysis components. The results above show that if the distance between the red axes is close to each other, there is a strong relationship, whereas if the axes are far from each other and opposite, there is a weak relationship. The relationship between the number of *A. pleuronectes* was positively correlated with salinity, depth, nitrate content, and silt substrate, with a

higher coarse sand and clay content. It negatively correlated with organic matter, chlorophyll-a, temperature, pH, dissolved oxygen, and silt substrate with more fine sand and gravel content.

The graph of research location points at the intersection of axes 1 and 2 (F1xF2) (Figure 3) shows a grouping of observation stations in the plane of intersection between positive axis 1 and negative axis 2, namely location points 1 and 2. Location points 1 and 2 are characterized by grouping depth variables, nitrate, clay, number of scallops, salinity, and coarse sand. The grouping of variables at this location point shows high values for depth, nitrate, clay substrate, and the number of scallops. The high nitrate content (0.664-0.682 mg.L^{-1}) at locations 1 and 2 resulted in a high total number of scallops (64-80 individuals) caught. This is because phytoplankton needs nitrate to carry out photosynthesis as food for the scallop *A. pleuronectes*. This was explained by Ratnaputri (2013) as a food source for shellfish. The role of nitrate for *A. pleuronectes* is related to its food source, namely phytoplankton, in photosynthesis and photoplasm formation.

The number of *A. pleuronectes* is also closely related to depth, where the deeper, at a certain depth, the greater the number of *A. pleuronectes* found, namely at station 1, continued to station 2 and station 3, and no samples were found at station 4. In the Principal Component Analysis (PCA) graph, depth is closely related to the clay substrate content. The deeper the water, the smoother the substrate will be. In this study, the substrate content at each station tended to be the same, namely silt substrate; therefore, silt substrate had little relationship to the number of shellfish obtained. However, other contents, such as clay substrates, are closely related to the depth and number of *A. pleuronectes*. This scallop lives in clayey silt sand, presumably because the morphology of its shell is flat and thin. The middle is convex, and the diameter is the same on both sides. The upper shell is brownish pink, and the lower part is white. The surface of the shell is smooth and slippery. Previous research conducted by Taufani (2016) showed that the analysis results using Shepard's triangle showed that the substrate texture class at each location was *A. pleuronectes* were found almost the same, namely dominated by clay, either muddy clay or muddy clay, and was found at a relatively deep depth, namely 18-26 m.

Amusium pleuronectes like to live in clayey substrates, and this is also due to their diet. This animal is sessile and has a pair of gills that function as filter feeders. Food is filtered through cilia and

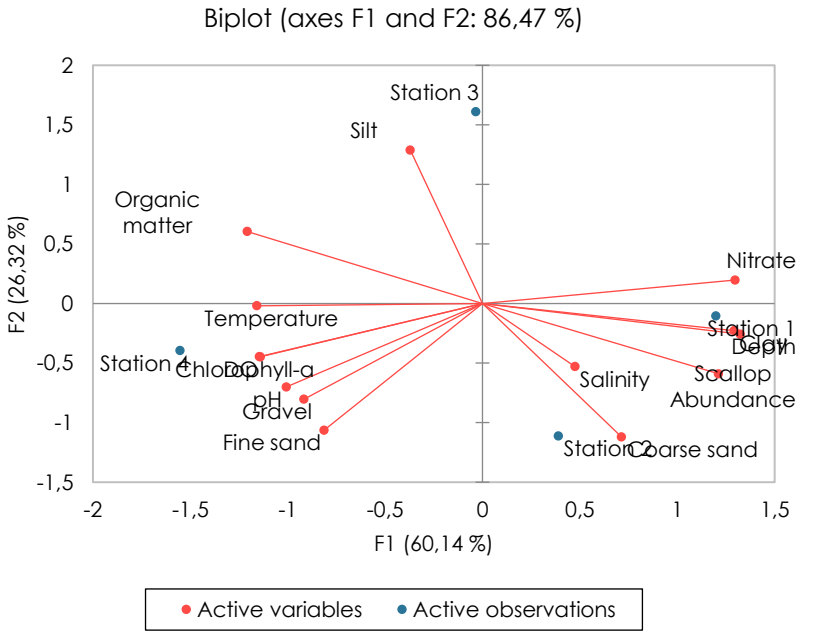

Figure 3. the relationship between scallop and field parameters

gills, and the type of food consists of various plankton and detritus deposits measuring less than 1 µ. In the process of filtering food, heavy metals, viruses, and bacteria can be filtered in and accumulate in the shellfish's body. According to (Andrew, 2016), shellfish have a high abundance of muddy substrates rich in organic matter and other essential elements such as calcium, potassium, magnesium, and nitrogen.

Meanwhile, the oxygen content on sandy substrates is relatively greater than on smooth substrates because they contain air pores that mix more intensively with the water above them. However, sandy substrates have few nutrients compared to smooth substrates, which are rich in nutrients but have little oxygen. Therefore, the clay graph tends to be far from organic matter in the Principal Component Analysis. This can be seen at station 4, where the clay fraction does not dominate, but the fine sand fraction, so scallops are not found at this station, but the content of organic matter and dissolved oxygen is higher than at other stations. The depth at station 4 is also low for *A. pleuronectes* habitat, namely 8 m, where scallops begin to appear at a depth of 19-32 m at stations 1-3. As Sahri *et al*. (2014) and Jamaludin *et al*. (2021) stated that the organic matter contained in marine sediments consists of particles originating from rock fragments and pieces of shell and skeletal remains from marine organisms or from terrestrial organic detritus that have been transported. Various natural media are deposited on the seabed over a long period and have undergone decomposition.

This study's Principal Component Analysis (PCA) also shows a close relationship between the number of *A. pleuronectes* and salinity. According to Liu *et al*. (1992) and Anti *et al*. (2014), salinity has an essential role in the life of organisms, for example, in the distribution of aquatic biota, and salinity is one of the quantities that role in the marine ecological environment. In this case, if the salinity content is too low or too high, it will cause the shellfish to experience stress (Yonvitner, 2007). The sea's salinity distribution is influenced by various factors such as water circulation, evaporation, rainfall, and river flow. In the research, the salinity value at each station did not fluctuate, ranging between 29-33 ‰. This value is above the quality standards set by the Minister of Environment Decree No. 51 of 2004 concerning seawater quality standards for marine biota.

In this study, the relationship between the scallops *A. pleuronectes* was slightly related to organic matter, chlorophyll-a, temperature, dissolved oxygen, pH, gravel substrate, silt, and fine sand. The chlorophyll-a value is related to temperature and dissolved oxygen, with high-temperature variables followed by high DO variables. This is because higher water temperatures cause increased photosynthetic activity from chlorophyll biota, such as phytoplankton in the waters, increasing the amount of dissolved oxygen produced from the photosynthesis process. The DO value tends to be higher at station 4 because it is closer to land and the estuary zone. Due to the large amount of photosynthetic activity from land, it is carried into the waters via rivers, and waters close to land tend to have a higher DO content than in the open ocean, which has spread along with currents, waves, and other factors. According to Zhang *et al.* (2020), the DO content in waters is determined by several factors, such as the photosynthesis process carried out by aquatic plants, the diffusion process from the air, water temperature, and the respiration process carried out by biota that occurs in the benthic zone. Dissolved oxygen content does not directly relate to the number of scallops. This is because shellfish can carry out anaerobic metabolism. However, this type of metabolism will result in shellfish lacking energy, affecting other activities such as reproduction and growth (Kharisma *et al*. 2012).

Based on the distribution of water pH obtained during the research, pH values ranged from 7.48 to 7.57. Changes in water pH are influenced by photosynthetic activity, temperature, and waste disposal (Nan *et al*. 2022). In the PCA graph, the pH value is related to the amount of chlorophyll-a. Where optimal pH can increase the diversity of phytoplankton to carry out photosynthesis. This was explained by Garini *et al*. (2021), who conducted research in Kendal Regency waters, stating that

the optimal acidity conditions for phytoplankton life ranged from 7 to 8.5. The pH value is influenced by several factors, including photosynthesis and respiration, temperature, and ions in the water, where photosynthesis will occur optimally if the pH value is under normal conditions. Waste disposal can also influence changes in pH. Widowati *et al*. (1999) added that in Pekalongan waters, *A. pleuronectes* scallops are found in waters with a pH that tends to be alkaline. Sea water is generally alkaline with a pH range between 7.5 and 8.5 because the chemical composition contained is relatively stable. Seawater also has a sound buffer system, so the pH value is relatively stable due to the proportional addition of alkali or acid compounds (Effendi (2003) also added that low pH values (6-6.5) can decrease in plankton diversity, thereby reducing food reserves for marine organisms.

A. pleuronectes are not evenly distributed in Kendal waters. Some abundances were relatively high, and others were low, and no one *A. pleuronectes* was found. Several ranges of bioecological parameters have determined the habitat existence of these scallops. Research conducted by Ernawati *et al*. (2011) in more expansive waters (from Semarang to Tegal) and Sahri (2014) in Brebes Regency also showed that the distribution of scallops in waters tends to be clustered, only found in specific locations.

CONCLUSION

This research concludes that scallops in Kendal waters have a relationship between size (L×W×H) and weight with a value of x<3, which is negative allometric where the growth in shell dimensions is faster than in shell weight. It also has a condition index value of 51.52 and is included in the medium condition index. The study's Principal Component Analysis (PCA) shows that the number of *A. pleuronectes* scallops in the waters of Kendal Regency is closely related to salinity, depth, nitrate content, and silt substrate, with a higher content of coarse sand and clay as a substrate. There is little relation to organic matter, chlorophyll-a, temperature, dissolved oxygen, pH, gravel substrate, silt, and fine sand.

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