



Relationships Between Habitat Conditions, Morphometry, and Nutritional Composition of the Pacific Oyster (*Crassostrea Gigas*) In Aceh Waters

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Abstract

Aceh is one of the provinces in Indonesia with a large sea area. This condition makes Aceh diverse in marine and fishery resources, including the *Crassostrea gigas* oyster. Currently, data on morphometric measurements to identify and develop *C. gigas* oyster commodities is still very limited. Therefore, this study aims to analyze the morphometry, habitat, and proximate composition of *C. gigas* oysters in the waters of Aceh. *C. gigas* oyster samples were collected by freely traversing various suspected oyster habitats. The search was carried out by checking for oysters attached to mangrove vegetation, wood, bridge iron, and rocks. A total of 50 *C. gigas* samples representing the entire population were used for morphometric analysis and nutritional composition. These water quality parameters were measured in situ with 5 repetitions, and measured where *C. gigas* was found. Length of *C. gigas* is 42.4 ± 11.6 mm, width is 29.5 ± 8.5 mm, thickness is 16.2 ± 5.7 mm, total weight is 13.1 ± 9.3 g, and meat weight is 1.4 ± 1.2 g. The effect of the length of *C. gigas* on the total weight of *C. gigas* is 51.2 %. Habitat parameter values: temperature is 31.7 ± 3.5 oC, salinity is 27.8 ± 5.8 , pH is 8.0 ± 0.4 , DO is 7.6 ± 2.3 mg/l, turbidity is 32.5 ± 28.0 , and the substrate is muddy and sandy. Ash content is 7.2 ± 3.4 %, moisture content is 8.9 ± 4.4 %, protein content is 51.0 ± 9.9 %, fat content is 12.9 ± 3.2 %, and carbohydrate content is 20.0 ± 7.9 %. PCA analysis showed that salinity, DO, and pH parameters were more important than other parameters for the nutritional composition of *C. gigas*.



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Abbreviations

C. gigas *Crassostrea gigas*

Introduction

Aceh is one of the provinces in Indonesia that has a large sea area.¹ Geographically, the waters of Aceh are divided into three distinct parts: the western part borders the Indian Ocean, the northern part borders the Andaman Sea, and the eastern part borders the Malacca Strait.² This condition makes Aceh abundant in fishery and marine biological resources, including shellfish (bivalvia).³ Bivalves that are aquacultured and live naturally in Aceh's waters are *Crassostrea gigas*.^{2,4} *C. gigas* has economic value as a food source.⁵⁻⁷ One type of oyster that has commercial and nutritional value and contains bioactive components is the *Crassostrea gigas* oyster.⁸⁻¹¹

Pacific oysters (*C. gigas*) can live attached to hard substrates (rocks, gravel), coarse sand, fine sand, mud, and clay.⁶ One of the methods used to study the factors that influence oyster life is by observing their morphometric characteristics.¹² Currently, morphometric analysis is widely used in medical science, botany,¹³ and biology.¹⁴ Morphometric analysis is used to analyze morphological and size differences among eight species of shellfish.¹⁵ Morphometric characteristics can be important indicators for understanding environmental conditions and geographical position.¹⁶ These morphometric measurements are important indicators in determining the nutritional content of *C. gigas* oysters.

The nutritional content of oysters consists of fat, protein, minerals, carbohydrates, unsaturated fatty acids, DHA, EPA, and important minerals such as Ca, Mg, Zn, Fe, and Cu.^{3,9} In addition, oysters also contain bioactive components, such as peptide compounds and amino acids,¹⁷ polysaccharides,¹⁸ oligosaccharides,¹⁹ polyphenols,²⁰ and essential fatty acids.²¹ Oysters also function as antimicrobials,²² antioxidants,²³ anti-inflammatory,²⁴ immunostimulants,²⁵ anticancer

agents,²⁶ antihypertensives,²⁷ blood sugar-lowering,¹⁸ cholesterol-lowering,²⁸ and probiotics.²⁹ The presence of nutrients and bioactive components makes oysters potentially suitable for development as functional foods.³⁰ Morphometric characteristics and nutritional composition are highly dependent on the habitat of *C. gigas* itself.

The growth and life of *C. gigas* are influenced by water quality factors such as salinity, temperature, pH, chlorophyll a, tides, dissolved oxygen, turbidity, and substrate.³¹⁻³³ The growth of *C. gigas* is very sensitive to environmental changes, such as a decrease in pH, which can inhibit shell growth.^{34,35} In addition, environmental changes affect the size and shape of the oyster itself.^{2,36} Currently, data on the morphometric characteristics, habitat, and nutritional composition of *C. gigas* oysters in Aceh waters are still very limited. This limited data is a constraint in the development of oysters as an economically valuable fishery commodity and aquaculture commodity. Several previous studies have not linked the morphometrics, habitat, and nutritional composition of *C. gigas*. Therefore, it is very important to conduct research related to the morphometric, habitat, and composition aspects of *C. gigas*. This study aims to analyze the morphometrics, habitat, and nutritional composition of *C. gigas* oysters in Aceh waters. This research is very important because it provides basic data needed for the development and management of *C. gigas* oysters in Aceh waters scientifically and sustainably.

Materials and Methods

Time and Location

This study was conducted from June to September 2025 in the province of Aceh (Figure 1), with the locations and coordinates presented in Table 1. Samples of *C. gigas* oysters were analyzed at the Integrated Agricultural Laboratory of the Faculty of Agriculture, Malikussaleh University.

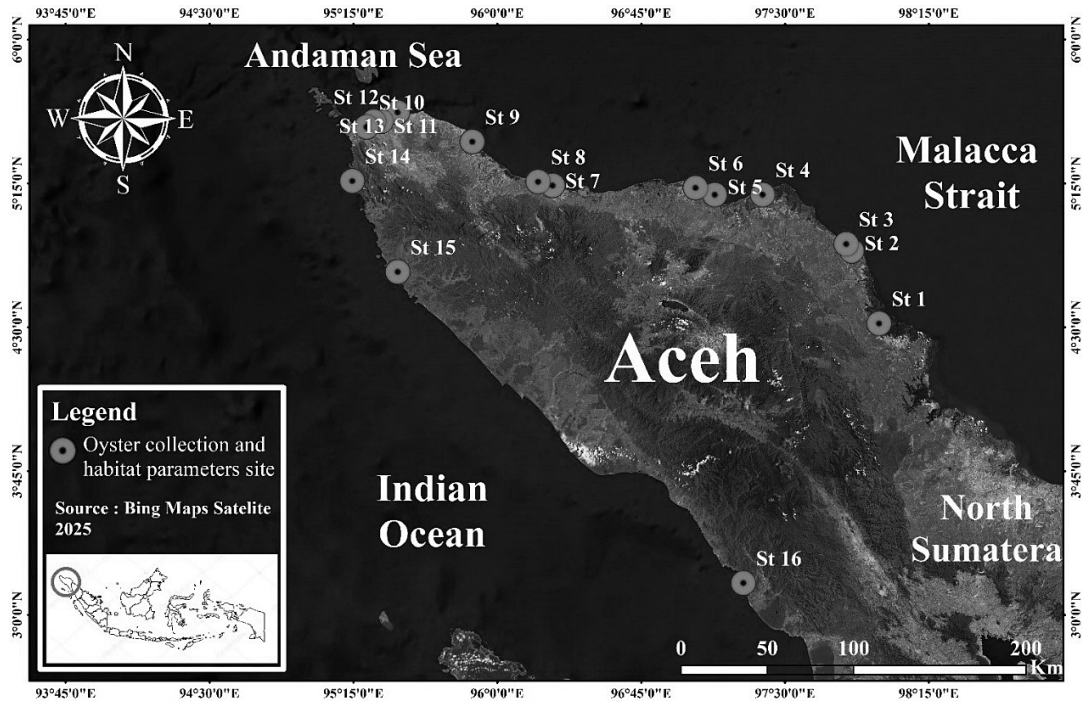


Fig. 1: Map of Aceh province and sampling location of *C. gigas*.

Table 1: Location and coordinates of sampling and habitat parameters of collected *C. gigas*.

Station	Location	Coordinate
1	Kuala Langsa, Langsa	4°29'52" N, 97°59'57" E
2	Paya Lipah, Peureulak	4°51'39" N, 97°54'22" E
3	Seumatang, Peureulak	4°50'48" N, 97°54'25" E
4	Bantayan, North Aceh	5°13'26" N, 97°25'41" E
5	Loskala, Lhokseumawe	5°12'07" N, 97°06'42" E
6	Rancong, North Aceh	5°14'04" N, 97°36'00" E
7	Mon Jambe, Bireun	5°15'16" N, 96°51'33" E
8	Alue Buya Pasie, Bireun	5°14'56" N, 96°44'41" E
9	Deah Pangwa, Pidie Jaya	5°25'29" N, 96°22'57" E
10	Lamnga, Great Aceh	5°37'01" N, 95°23'57" E
11	Krueng Cut, Banda Aceh	5°35'06" N, 95°21'19" E
12	Tibang, Banda Aceh	5°35'10" N, 95°20'51" E
13	Lamingin, Banda Aceh	5°35'05" N, 95°19'40" E
14	Glee Bruek, Great Aceh	5°11'53" N, 95°17'12" E
15	Rigaih, Aceh Jaya	4°40'04" N, 95°33'41" E
16	Pasi Kuala Bau, South Aceh	3°06'08" N, 97°18'12" E

Procedures

Sampling *C. gigas*

The *C. gigas* oyster samples were collected from waters in Aceh Province, with locations based on

(Octaviana *et al.* 2014)¹ in Aceh Besar, (Purba *et al.* 2017)³⁷ in the waters of Langsa City, (Erlangga *et al.* 2022)⁴ in the waters of Lhokseumawe City, (Erniati *et al.* 2024)³ in the waters of North Aceh, and also

in the waters of Meulaboh and Aceh Jaya based on information on the presence of oysters from the community. *C. gigas* samples were collected from June to September 2025. *C. gigas* oyster samples were collected by freely traversing various suspected oyster habitats (Figure 2). The search was carried out by checking for oysters attached to mangrove

vegetation, wood, bridge iron, and rocks when the sea water was low tide. A total of 50 specimens (Gongora-Gomes *et al.* 2018)³⁸ *C. gigas* representing the population at each station, were taken randomly and then used for morphometric and nutritional composition analysis.



Fig. 2: Sample collection documentation.

Morphometrics of *C. gigas*, Habitat, and Nutritional Composition,

A total of 50 *C. gigas* samples representing the entire population were used for morphometric analysis. The sample is washed using clean water, then drained until there is no more mud attached. The parts of *C. gigas* measured included shell length, shell width, shell thickness (Figure 3), meat weight, and total weight. The habitat of *C. gigas* was analyzed by measuring water quality parameters. Water quality measurements included temperature, salinity, DO, pH, turbidity, and substrate. Temperature measurements were made using a thermometer, salinity using a refractometer, DO using a DO meter, pH using a pH meter, turbidity using a turbidity meter, and the substrate was viewed visually. These water

quality parameters were measured in situ with 5 repetitions, and measured where *C. gigas* was found.

C. gigas samples were cleaned of sand and washed thoroughly with water. The part taken was the *C. gigas* meat found inside the shell. The washed meat was then drained and dried in an oven at 60 °C for 2 x 24 hours or until the moisture content reached 10-12%. The dried oyster samples were ground into powder. This oyster powder was used for proximate analysis. The proximate composition was analyzed based on AOAC (2005),³⁹ which includes moisture content, ash content, fat content, protein content, and carbohydrate content, with one repetition at each station. Carbohydrate analysis was conducted by difference.

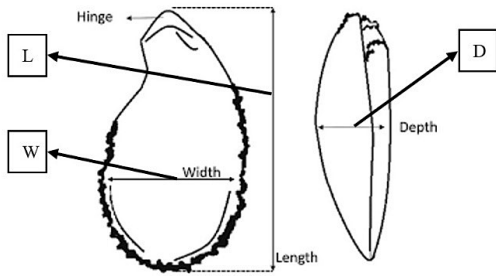


Fig. 3: Morphometric measurements of *C. gigas* include shell length (L), shell width (W), and shell thickness (D) (Mizuta and Wikfors 2018; Liu et al. 2024).^{40,12}

Data Analysis

One-way ANOVA tests were used to examine significant differences in the morphometric and

habitat parameters of *C. gigas* at each station ($P < 0.05$) by using M. excel.⁴¹ Meanwhile, linear regression analysis was used to examine the relationship between the length and weight of *C. gigas* by using M. excel.⁴² Cluster analysis was used to examine the similarity between *C. gigas* habitats in the Aceh Waters based on the Bray-Curtis similarity index by using Past Pro 4. The data analysis used to determine the most influential parameters of habitat on nutritional composition was PCA testing (PCA was based on normalized z-scores) by using Past Pro.⁴³

Results

Morphometrics of *C. gigas*

Morphometric characteristics of *C. gigas* at each station in Aceh waters (Table 2), average morphometric values of *C. gigas* (Figure 4), and length-weight relationship of *C. gigas* (Figure 5).

Table 2: The average morphometric value and one-way ANOVA test of *C. gigas* at each station in the waters of Aceh

The average morphometric value of <i>C. gigas</i>					
Station	Length (mm)	Width (mm)	Depth (mm)	Total Weight (g)	Meat Weight (g)
1	48.11 ± 11.52	30.04 ± 7.65	15.68 ± 3.82	16.93 ± 11.17	1.78 ± 1.17
2	37.71 ± 6.58	26.90 ± 4.69	14.12 ± 3.65	8.66 ± 3.92	1.09 ± 0.91
3	43.17 ± 10.44	29.86 ± 9.31	17.56 ± 5.16	17.59 ± 13.63	1.08 ± 0.76
4	32.54 ± 7.43	23.27 ± 5.55	13.74 ± 3.80	7.75 ± 4.65	1.14 ± 1.20
5	39.76 ± 6.72	27.82 ± 6.00	14.90 ± 4.85	10.29 ± 4.91	1.06 ± 0.60
6	37.74 ± 6.58	26.25 ± 4.83	12.87 ± 3.54	7.70 ± 3.31	0.76 ± 0.45
7	50.84 ± 9.51	32.60 ± 6.90	16.00 ± 4.85	16.66 ± 8.02	2.04 ± 0.87
8	37.20 ± 8.62	24.11 ± 3.86	13.86 ± 1.13	6.71 ± 2.35	1.01 ± 0.64
9	36.83 ± 6.67	27.94 ± 5.36	16.82 ± 5.16	10.20 ± 5.35	0.73 ± 0.54
10	45.38 ± 10.18	33.35 ± 10.11	19.17 ± 8.81	16.74 ± 10.42	1.84 ± 1.14
11	50.36 ± 11.26	35.63 ± 9.56	19.12 ± 5.63	20.43 ± 12.49	2.63 ± 1.78
12	62.32 ± 9.05	41.57 ± 7.29	22.71 ± 5.33	22.32 ± 5.80	2.01 ± 1.08
13	46.63 ± 9.39	35.42 ± 8.87	19.38 ± 5.29	19.31 ± 8.66	2.53 ± 1.67
14	42.52 ± 7.84	28.57 ± 6.75	15.11 ± 5.92	15.57 ± 6.64	1.38 ± 0.76
15	36.14 ± 8.80	25.51 ± 6.27	16.79 ± 6.12	8.47 ± 4.65	0.46 ± 0.42
16	30.92 ± 3.91	23.20 ± 4.92	11.68 ± 3.23	4.47 ± 2.31	0.42 ± 0.28
ANOVA Test	P < 0.05	P < 0.05	P < 0.05	P < 0.05	P < 0.05

Note: Average morphometric values with standard deviation.

Habitat of *C. gigas*

Habitat parameter values for *C. gigas* in Aceh waters (Table 3), average habitat parameter values for *C.*

gigas (Figure 6), and similarity of *C. gigas* habitat parameters between stations (Figure 7).

Table 3: Average values One Way ANOVA of *C. gigas* habitat parameters in Aceh waters.

Average values of <i>C. gigas</i> habitat parameters in Aceh waters						
Stasiun	Temperature (oC)	Salinity (‰)	pH	DO (mg/L)	Turbidity (NTU)	Substrate
1	35.5 ± 1.6	21.6 ± 0.8	7.7 ± 0.3	10.0 ± 2.2	21.0 ± 3.0	Sandy mud
2	34.5 ± 0.0	26.8 ± 0.4	7.4 ± 0.1	7.3 ± 0.7	92.4 ± 24.5	Sandy mud
3	31.8 ± 0.6	27.6 ± 0.5	7.7 ± 0.0	8.3 ± 0.2	61.0 ± 16.9	Sandy mud
4	35.4 ± 0.2	27.6 ± 0.5	8.3 ± 0.0	8.2 ± 0.9	30.2 ± 3.2	Sandy mud
5	31.7 ± 0.1	24.2 ± 0.4	7.5 ± 0.0	2.9 ± 0.0	12.4 ± 1.8	Sandy mud
6	30.2 ± 0.4	28.2 ± 0.8	8.0 ± 0.0	7.2 ± 0.4	14.8 ± 5.5	Muddy sand
7	29.6 ± 0.8	31.8 ± 0.8	8.2 ± 0.1	11.3 ± 0.6	56.4 ± 8.5	Muddy sand
8	31.5 ± 0.0	11.8 ± 0.4	7.6 ± 0.0	3.2 ± 0.4	18.8 ± 4.6	Muddy sand
9	36.3 ± 0.1	28.6 ± 0.8	8.3 ± 0.0	9.1 ± 0.0	84.6 ± 30.5	Sandy mud
10	33.5 ± 0.4	31.0 ± 0.7	7.8 ± 0.0	6.7 ± 0.2	28.3 ± 6.4	Muddy sand
11	31.1 ± 0.2	30.8 ± 0.4	8.2 ± 0.0	8.6 ± 0.1	10.3 ± 2.3	Muddy sand
12	34.2 ± 0.6	34.8 ± 0.3	8.5 ± 0.0	10.5 ± 0.5	17.7 ± 3.2	Sandy mud
13	30.3 ± 0.3	32.0 ± 0.0	8.4 ± 0.2	6.3 ± 0.1	17.7 ± 4.2	Sandy mud
14	30.3 ± 0.4	30.0 ± 0.0	8.1 ± 0.0	7.7 ± 0.1	21.4 ± 6.6	Muddy sand
15	30.8 ± 0.0	25.2 ± 0.8	8.5 ± 0.2	7.1 ± 0.1	4.8 ± 0.5	Muddy sand
16	21.0 ± 0.0	33.5 ± 0.2	7.8 ± 0.0	7.3 ± 0.1	28.3 ± 14.6	Muddy sand
ANOVA Test	P < 0.05	P < 0.05	P < 0.05	P < 0.05	P < 0.05	P < 0.05
Quality standard						
Indonesian Regulation						
No. 22/20 2143	28 – 32	28 – 39	7 – 8.5	> 5	< 5	Natural

Note: Values are mean ± SD and quality standards for *C. gigas* life.

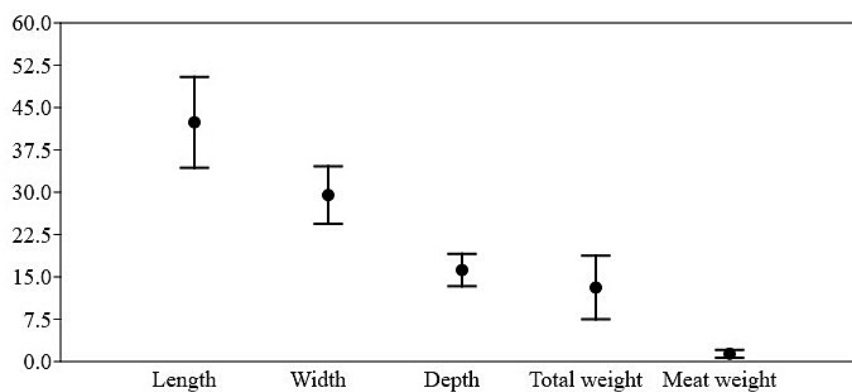


Fig. 4: Average morphometric values of *C. gigas* in Aceh waters

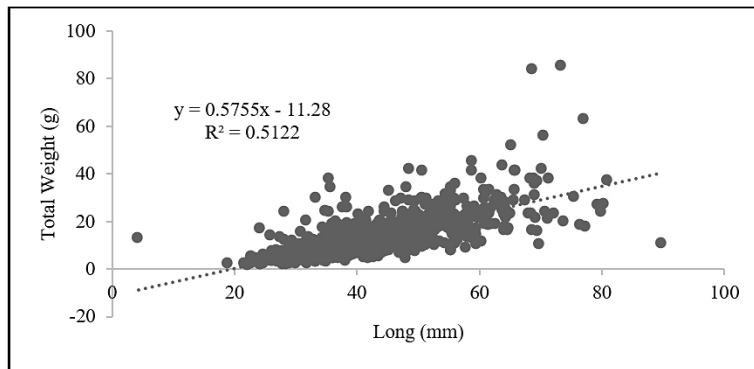


Fig. 5: Analysis of the correlation of *C. gigas* length on total *C. gigas* weight.

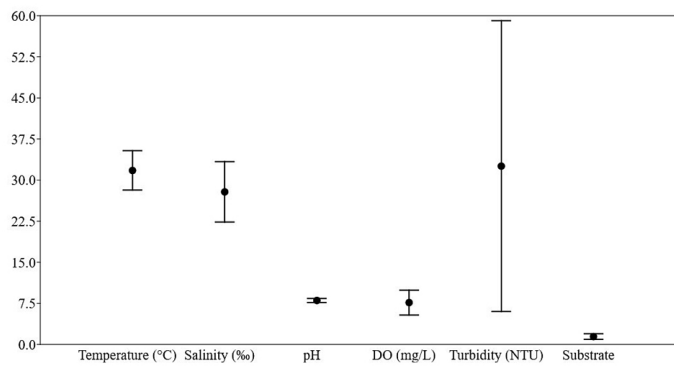


Fig. 6: Average values of *C. gigas* habitat parameters in Aceh waters.

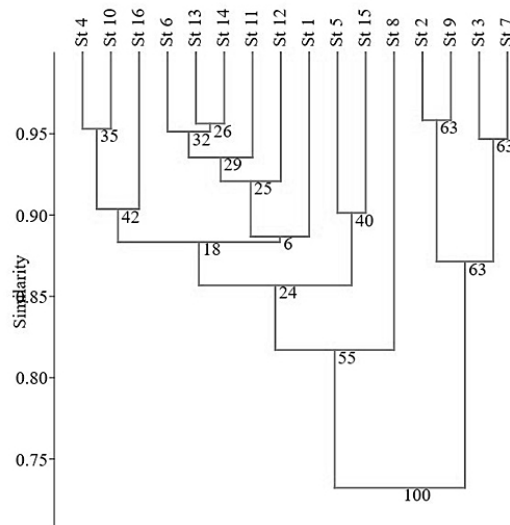


Fig. 7: Analysis of the similarity of *C. gigas* habitat parameters in Aceh waters.

Nutritional composition of *C. gigas*

Nutritional composition values of *C. gigas* from

Aceh waters (Table 4), PCA analysis of habitat parameters (Figure 8).

Table 4: Nutritional composition values of *C. gigas* from Aceh waters.

Station	Ash Content (%)	Water Content (%)	Protein Levels (%)	Fat Content (%)	Carbohydrate Content (%)
1	12.24	15.94	31.23	14.60	25.99
2	6.54	9.30	44.94	14.25	24.97
3	5.08	8.67	49.58	14.75	21.92
4	5.94	10.25	35.69	12.40	35.72
5	5.42	12.67	62.01	12.90	7.00
6	6.86	13.00	60.85	13.00	6.29
7	6.50	12.78	41.88	15.55	23.29
8	11.36	16.01	46.76	7.75	18.12
9	5.48	3.99	63.86	11.65	15.02
10	4.26	8.75	57.13	13.15	16.71
11	3.96	8.67	54.92	21.60	10.85
12	6.44	5.87	52.36	9.50	25.83
13	5.38	6.65	55.45	12.70	19.82
14	5.62	2.35	57.23	11.20	23.60
15	16.86	5.94	40.26	8.65	28.29
16	7.06	1.67	61.52	13.20	16.55
Mean	7.19	8.91	50.98	12.93	20.00
SD	3.41	4.40	9.96	3.18	7.87

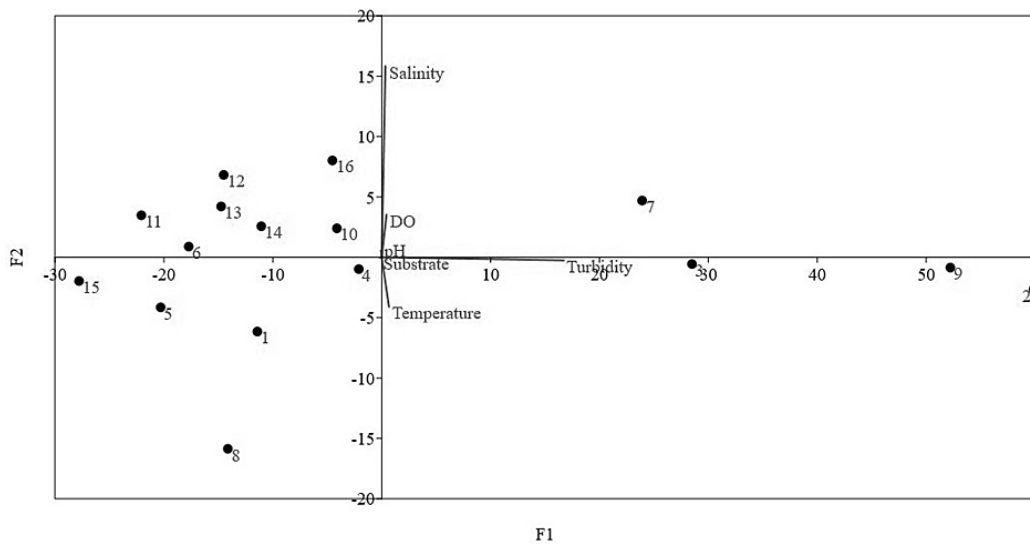


Fig. 8: PCA analysis of the relationship between habitat parameters and the nutritional composition of *C. gigas* in Aceh waters.

Discussion

The ANOVA test results show that there are significant differences among stations (Table 2). The high morphometric values at station 12 are caused by the location being one of the areas where oysters,

including *C. gigas*, are cultivated, so that oysters are not exploited when small. *C. gigas* oysters at station 12 are harvested when they reach a sufficient size. In addition to station 12, there are several other stations that are also *C. gigas* cultivation areas,

namely stations 1, 7, 10, 11, and 13. The location of each station distinguishes between naturally grown *C. gigas* and cultivated *C. gigas*. The morphometric size of *C. gigas* found in Aceh waters is relatively small due to the high level of exploitation of *C. gigas* in its natural habitat. This exploitation has made *C. gigas* > 5 mm very rare. The community exploits *C. gigas* for their own consumption as well as for commercial purposes. If *C. gigas* are harvested at a small size, it can eliminate many individuals before they have a chance to reproduce, rapidly reducing *C. gigas* stocks in the wild. *C. gigas* can be cultivated extensively.⁴⁴⁻⁴⁶ The morphometry of farmed *C. gigas* is better than that of naturally occurring *C. gigas*.⁴⁷ The results of the ANOVA test can be attributed to factors such as species, shell shape (length, height, and width), and environmental conditions (Diaz and Campos 2014).⁴⁸ In addition, oyster morphometry is also influenced by geographical factors.²

The coefficient of determination (R^2) value from the linear regression test is 0.5122. This value indicates that the effect of *C. gigas* length on the total weight of *C. gigas* is 51.22%. In addition to length, the width and thickness of *C. gigas* are thought to be factors that affect the total weight of *C. gigas*. In conditions where *C. gigas* forms colonies, the growth of shell length is greatly limited by the individuals within the colony itself. This can inhibit the growth of the length and width of the *C. gigas* shell. This situation also allows for greater growth in shell thickness compared to the growth in length and width of the *C. gigas* shell. The growth of oyster weight is greatly influenced by the growth of oyster length.⁴⁹ The morphometric growth of oysters is also influenced by the nutrients available in the water.⁵⁰

Aceh's water conditions are generally optimal for *C. gigas* life, except for several parameters at certain stations. The average temperature is optimal, but Station 16 is cooler due to protection by mangroves and being an enclosed sea. Average salinity and pH are within ideal quality standards; the lower salinity in the estuary (*C. gigas* natural habitat) and the high freshwater concentration at Station 8 are still safe, and the favorable pH supports shell growth. However, Dissolved Oxygen (DO) content is low at Stations 5 and 7 due to the lack of oxygen-producing vegetation and dependence on tides. Average turbidity generally exceeds the quality

standards, indicated by wide standard deviations. High turbidity is caused by erosion from new ponds (Station 2) and the influx of turbid sediment from the river (Station 9). The substrate in most areas is dominated by sandy mud, which is consistent with the natural habitat of *C. gigas*, which consists of sand and mud. In general, significant deviations in water quality (especially turbidity and DO) at some stations are key factors driving the morphometric variations observed across locations, where organisms adapt their physical form to cope with resource limitations or stresses. Shell growth can slow down at very high temperatures due to increased metabolism that cannot be matched by feed intake.

The ANOVA test results show that the average values of temperature, salinity, pH, DO, and turbidity differ significantly between stations. The cluster analysis results show that the stations with the highest similarity are station 2 with 9, station 13 with 14, and station 4 with 10. The habitat of *C. gigas* between cultivation and natural habitats showed several similarities, such as at stations 3 and 7, stations 4 and 10, and stations 13 and 14. These similarities in the habitat characteristics of *C. gigas* indicate that although they are geographically different, the characteristics of the habitat parameters are similar. The habitat parameter conditions in the tidal zone cause rapid changes in environmental pressure. The cultivated habitat of *C. gigas* is more controlled than its natural habitat. Differences in habitat parameters will affect the morphometry and nutritional composition of *C. gigas*. In addition, *C. gigas* has a high adaptability and resistance to environmental changes. *C. gigas* plays an important role in estuarine and coastal marine habitats. *C. gigas* is a highly tolerant species that can grow rapidly and is more suited to living on hard substrates in tidal zones up to a depth of 40 m.⁵¹ Its resilience allows *C. gigas* to be cultivated worldwide⁵² and *C. gigas* has become an invasive species that often outcompetes native bivalves due to its rapid growth.⁴⁵ The habitat of cultivated *C. gigas* shows differences from the habitat of naturally growing *C. gigas*.⁵³ *C. gigas* can survive in extreme water conditions, allowing it to be found in a variety of habitats.^{44,46} *C. gigas* must cope with highly dynamic and stressful environmental conditions during their life in the intertidal zone.⁵⁴ The intertidal zone is a harsh environment, where *C. gigas* is exposed

to extreme abiotic fluctuations that cause them to often live close to their physiological limits.⁵⁵⁻⁵⁷ Changes in environmental conditions can affect oyster abundance.⁵⁸ Salinity stress,²³ substrate,⁵⁹ dissolved oxygen concentration, and increased temperature can affect water conditions, thereby impacting energy-intensive metabolic activities.⁵⁶ In addition, a decrease in pH can have a direct impact on the growth of *C. gigas* shells.⁵⁹

C. gigas contains 50.97% protein, followed by carbohydrates and fat. Several observation stations report that when protein content is high, carbohydrate content is low. In general, carbohydrates are produced more by plants than by animals. The differences in the nutritional composition of *C. gigas* in Aceh waters are due to differences in habitat conditions. A range of habitat parameters that are still within quality standards will have an impact on oysters that have good nutritional content. PCA test results show that salinity, DO, and pH are key parameters in determining the nutritional composition of *C. gigas*. PC1 showed 56% of variance, dominated by DO. PC2 showed 50% of variance, dominated by pH and salinity. Station 7 is characterized by salinity, DO, and pH parameters, while stations 2, 3, and 9 are characterized by temperature, substrate, and turbidity parameters. Other stations are not characterized by any parameters. Low DO is a critical issue. This condition directly causes severe physiological stress, which is reflected in smaller oyster size and weight (morphometric variation) and poor proximal composition (low glycogen). Oysters in high turbidity areas often have lower meat weights and poor glycogen storage levels. This occurs because energy is spent processing large amounts of non-food particles rather than on meat growth. The further a parameter deviates from optimal conditions, the greater the physiological stress experienced by oysters, and the more energy is allocated to survival, ultimately reducing the accumulation of glycogen, protein, and fat. The nutritional composition of oysters is influenced by species and habitat differences.⁵⁹ The protein content of cultured oysters is higher than that of naturally occurring oysters.⁶⁰ Water content is greatly influenced by the physical condition of the meat, physiology, and reproductive cycle.⁶⁰ Variable temperatures cause changes in

metabolism and protein accumulation in oyster tissue.⁵⁶ pH is one of the most influential parameters on the nutritional composition of oysters.⁵⁹

Conclusion

Aceh waters have enormous potential for *C. gigas* cultivation, supported by a favorable habitat. The habitat creates the conditions for *C. gigas* adaptation. These conditions determine how energy is used, which is reflected in the oyster's morphometrics and nutritional quality. The high protein content positions aceh oysters as a high-quality functional food source, thus becoming a strong asset for branding local acehnese products as healthy premium products. The Aceh government can use this data to establish special coastal zoning areas for oyster development to improve the economic standard of Aceh's coastal fishermen without damaging the ecosystem.

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Conflict of Interest

The authors do not have any conflict of interest.

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This statement does not apply to this article.

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This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials.

Permission to Reproduce Material from Other Sources

Not applicable.

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