Morphometric analysis of spiny lobster *(Panulirus penicillatus)* and bamboo lobster *(Panulirus versicolor)* in Sabang Waters

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Abstract. This research aims to analyze morphometrics of *(P. penicillatus*) and (*P. versicolor*) in waters of Sabang. A total of 50 samples from each species of *P. penicillatus* and *P. versicolor* were used for morphometric analysis using Traditional Morphometric and Truss Morphometric approaches. Morphological analysis indicated that both lobster species are categorized into two distinct groups. Traditional morphometric character testing using ANOVA showed that species differences significantly influence the variation in morphological characters ($P<0.05$) in both lobsters. Further Duncan post hoc tests revealed that four characters (HL), (CHW), and (CHL)) differed significantly between the species. *P. penicillatus* shared three characters similar to *P. versicolor,* namely (HL), (CHW), and (CHL). This similarity is based on the shape of HL, CHW, and CHL in both lobsters. In the Truss Morphometric character testing with ANOVA, it was found that species differences affect the characters significantly ($P<0.05$). The Duncan post hoc test revealed that five characters ([A1, A3], [B1, B3], [C5, C6], D4, [D5, D6]) differed significantly between species. DFA resulted in 1 function, with an eigenvalue of 27.595, indicating that it explains 100% of the total variance. The morphological characters that significantly contribute to the differentiation between species are A1, B1, C5, A5, and D5.

1 Introduction

The diversity of lobsters on the island of Sumatra, especially in Aceh, is quite comprehensive. A total of 6 lobster species were found [1]. The most dominant species found in the waters of Aceh include *Panulirus ornatus, Panulirus versicolor, Panulirus penicillatus, Panulirus homarus, Panulirus longipes, and Panulirus polyphagus.* Sabang's waters are located in the coastal area and are surrounded by various small islands. This extensive area includes many beaches, which are the main locations for tourism development and the potential for abundant marine resources, including lobster *(Panulirus spp.)* [2]. There are five regions in Indonesia known for lobster production, including Cilacap, Yogyakarta, Gresik, Aceh, and Lombok [3], and the lobster business is a sector that can help improve and enhance people's livelihoods [4].

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The Stone Lobster *(Panulirus penicillatus)* is characterized by a body color ranging from green to brown. It has long antennae with branched antennules. This lobster species lacks claws, but in females, there are imitation claws at the fifth walking leg's end, which function to tear the sperm pouch during fertilization. The carapace is somewhat round and spiky. The tips of the carapace and the area between the eyes are orange and blue. The frontal horns have a black pattern with white lines encircling them. The antennular plate has two pairs of separated spines, with several small spines among the main spines. The antennular flagella are brown with circular white lines. The differentiation between males and females is based on the gonopore's location on the walking legs and swimmerets [5]

The Bamboo Lobster is characterized by a distinct bright green color with transverse white lines bordered by black. There are no transverse grooves and hair on the surface of the abdominal segments, except at the rear edge and indentation on the sides. The antennae are red, and each leg has horizontal black to yellowish lines [6].

The differences between male and female lobsters can be clearly observed from their body structure. In male lobsters, the gonopore is located at the base of the fifth walking leg. All walking legs of male lobsters have the same shape, including the fifth walking leg which has sharp claws at its tips. The first swimmeret in male lobsters consists of a single plate. In contrast, in female lobsters, the gonopore is located at the base of the third walking leg. The fifth walking leg in female lobsters has an imperfect claw and branches into three, serving the function of carrying fertilized eggs into the brood pouch during the hatching process. The first swimmeret in female lobsters consists of two plates, with the outer plate larger than the inner one. The inner plate has two branches, being rigid and thin [7].

2 Material and Method

2.1 Time and Site

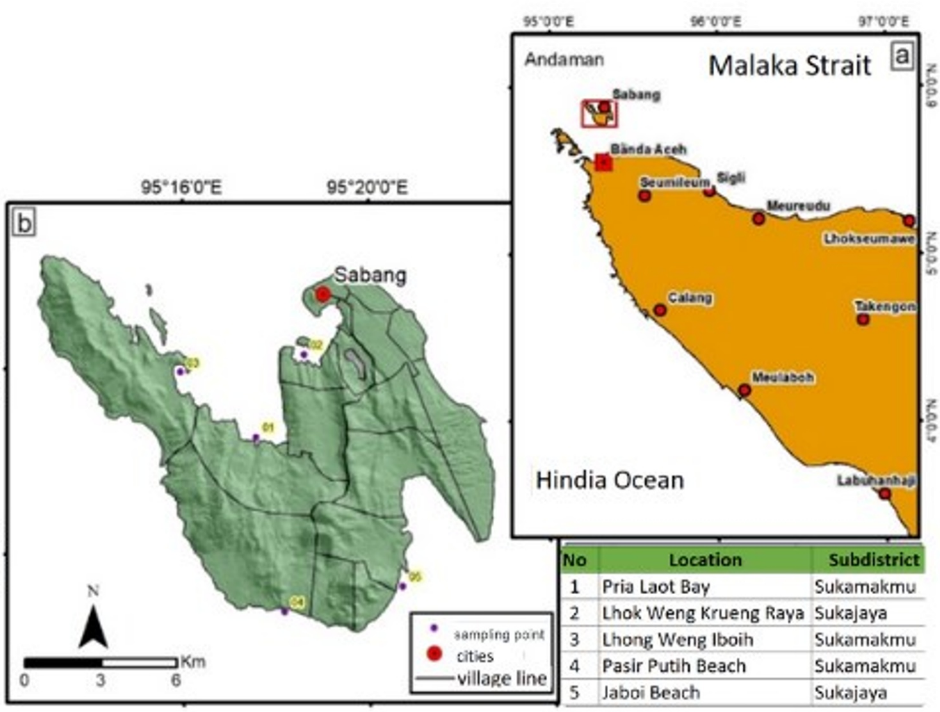

Fig. 1 Map of lobster fishing locations in Sabang waters

This research was conducted in the Coastal area of Sabang City using the Purposive Sampling method, with samples obtained from the catches of local fishermen. The sampling locations were in the areas of Pria Laot Bay, Lhok Krueng Raya, Lhok Weng (Iboih), and Pasir Putih Beach in the waters of Sabang. The research lasted for 6 months from February to July 2023. A total of 50 samples for each species were collected for morphometric measurements. Lobster harvesting in the waters of Sabang employs a very simple method. The most common technique involves diving using basic scuba diving equipment such as an oxygen tank, diving mask, and webbed fins. Activities are conducted at night and utilize illumination to attract lobsters out of coral crevices. The capture process involves using hands to catch the lobsters. This technique requires caution to avoid injuries from the sharp claws of the lobsters. Once obtained, the lobsters are placed in a net before being transported to the shore.

The lobster fishing in several locations is conducted while simultaneously measuring the morphometrics of permitted lobsters in accordance with the government's efforts to address the sustainability of lobster harvesting through the Minister of Marine Affairs and Fisheries Regulation Number: 12/PERMEN-KP/2020 Regarding Lobster Fishing *(Panulirus spp.)*. This regulation governs the capture of lobsters, allowing those with a carapace length greater than 8 cm to be caught. It also mandates the release of lobsters in a gravid condition and requires the documentation of each captured lobster.

The lobster samples were previously placed in Polystyrene boxes, and they were then transported to the Laboratory of Marine Biology, Faculty of Marine and Fisheries, Syiah Kuala University for morphometric measurements and documentation. During the documentation process, it was crucial for the samples to remain intact for a detailed morphometric examination of *P. penicillatus* and *P. versicolor.*

Measurements are taken using calipers with a precision of 0.01 cm. Morphometric measurements follow the method proposed by Brezky and Doyle in 1988. The observed parameters include the head, body, and tail sections of the lobster [8]

Morphometric data were analyzed using univariate analysis (one-way ANOVA) followed by post hoc test using Duncan's and multivariate analysis (Discriminant Function Analysis, DFA) with SPSS. The following are the general steps for morphometric analysis using univariate analysis (one-way ANOVA) and multivariate analysis (Discriminant Function Analysis) in SPSS.

2.2 Collection of Lobster Samples

Additionally, there is a significant role in the policy regarding adult lobster populations to obtain an overview of gender ratios, growth, condition indices, and mortality in specific spatial and temporal contexts. Research on high-value economic lobsters is also essential [5]. Previously, fishermen placed trap nets daily in proximity to suitable crevices along the rocky seabed, secured with weights and floats. In the morning, fishermen visited the fishing locations and brought the nets along with the captured lobsters to the shore. Night trapping was also employed as lobsters are more active during the night [6].

2.3 Lobster Morphometric Measurements

Morphometric measurements (truss morphometric) divided the lobster's body into four parts, denoted as A, B, C, and D (truss cells). From each part, six longitudinal and diagonal lines (truss lengths) were measured using calipers with a precision of 0.01 cm. The morphometric measurements followed the method [7]. The observed parameters included parts of the head, body, and tail.

Truss morphometrics is a technique used to measure the distances at specific points on the body, based on reference points. These Truss morphometric points are connected by horizontal, vertical, and diagonal Truss morphometric distances, allowing for a detailed and specific analysis of the fish's body shape. Therefore, Truss morphometrics is preferred over conventional morphometrics because it provides a more comprehensive picture of body shape due to the limited number of distances in conventional morphometrics [8].

Truss Morphometric measurement analysis, statistical methods used are generally similar to those used in conventional morphometric analysis, including descriptive statistics, univariate analysis, multivariate analysis, or discriminant analysis [9]. Lobsters are suitable subjects for repeated body measurements due to their hard exoskeleton and body segments. Digital techniques have also been used to measure lobsters. A total of 24 body parts were measured in lobster samples [10].

Several of the observed samples focused on the morphological characteristics of the cephalothorax and abdomen carapace. Morphological features examined included antenna type, antennula type, the number of spines on the antennula plates, color patterns on the carapace, abdomen, and pereiopod, eye location, and antenna type. Gender determination through observation of genital opening placement on the base of lobster pereiopod legs, the presence or absence of branching development on the 5th pereiopod leg (second walking leg), and the presence or absence of endopleopod development was conducted. [14]

Morphometric observations on lobsters were also performed by measuring total length, carapace (cephalothorax) length, abdomen segment length, and tail length. Total length measurement started from the anterior end of the carapace near the antennula plate spine to the telson's tip along the midline. Carapace length measurement began from the anterior end of the carapace near the antennula plate spine to the carapace's posterior edge along the midline. [15].

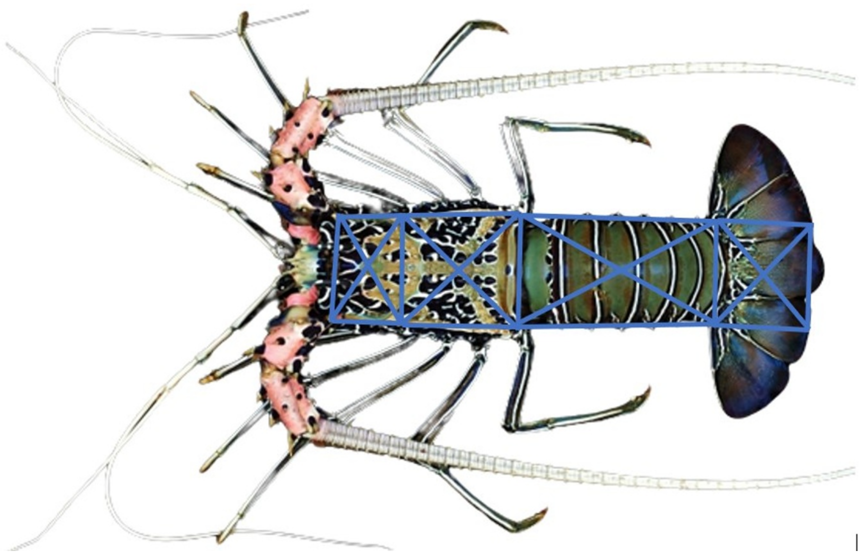

Fig. 2. Truss Morphometric Method for *Panulirus spp*

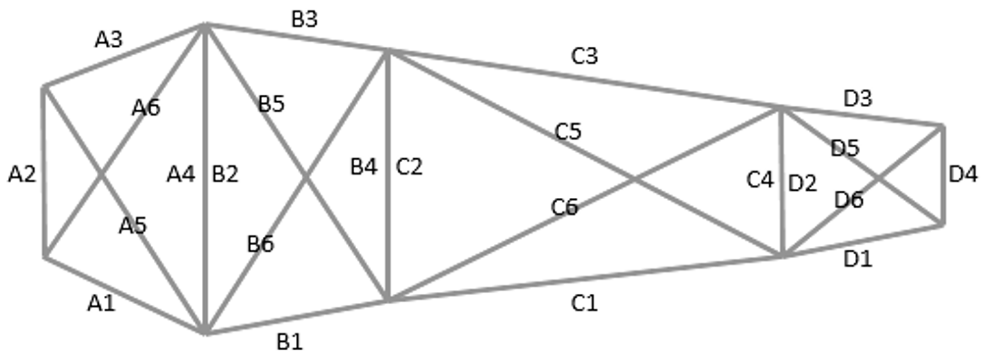

Fig. 3. Lobster parts in morphometric truss measurements

Table 1. Parameters for Truss Morphometric Observation of Lobsters

Body part	Symbol	Information
Front Head	A1	Distance from the widest left carapace point to the base of the left eye stalk.
	A2	Distance between the right and left eye stalks
	A3	Distance from the widest right carapace point to the base of the left eye stalk
	A4	Distance between the widest carapace points (front of the head)
	A5	Diagonal from the left rear carapace point to the right eye
	A6	Diagonal from the right rear carapace point to the left eye
Back of Head	B1	Distance from the rear carapace point to the widest left carapace point
	B2	Distance between the widest carapace points (front of the head)
	B3	Distance from the rear carapace point to the widest right carapace point
	B4	Distance between the two rear carapace points
	B5	Diagonal from the left rear carapace point to the widest right carapace point
	B6	Diagonal from the right rear carapace point to the widest left carapace point
Abdomen	C1	Distance from the left rear abdomen point to the front left abdomen point
	C2	Distance between the two rear abdomen points
	C3	Distance from the right rear abdomen point to the front right abdomen point
	C4	Distance from the rear right abdomen point to the left side
	C5	Diagonal from the left rear abdomen point to the right front abdomen point
	C6	Diagonal from the right rear abdomen point to the left front abdomen point

Tail (Telson)	D1	Distance from the left rear telson point to the front left telson point
	D2	Distance between the two rear abdomen points
	D3	Distance from the right rear telson point to the front right telson point
	D4	Distance from the rear right telson point to the left side
	D5	Diagonal from the left rear telson point to the right front telson point
	D6	Diagonal from the right rear telson point to the left front telson point

(Abinawanto *et, al,* 2018)

The morphometric character measurements were conducted based on the following parameters: Ocular carapace length (OCL), Propodal length (PL), Dactyl length (DL), Chela length (CL), Chela width (CW), Cephalon width (CW), Thorax width (TW), Carapace length (CL), Carapace width (CW), Abdominal length (AL), Telson length (LT), Telson width (TW), Maximum abdomen width (MAW) dan Total weight (W) [11].

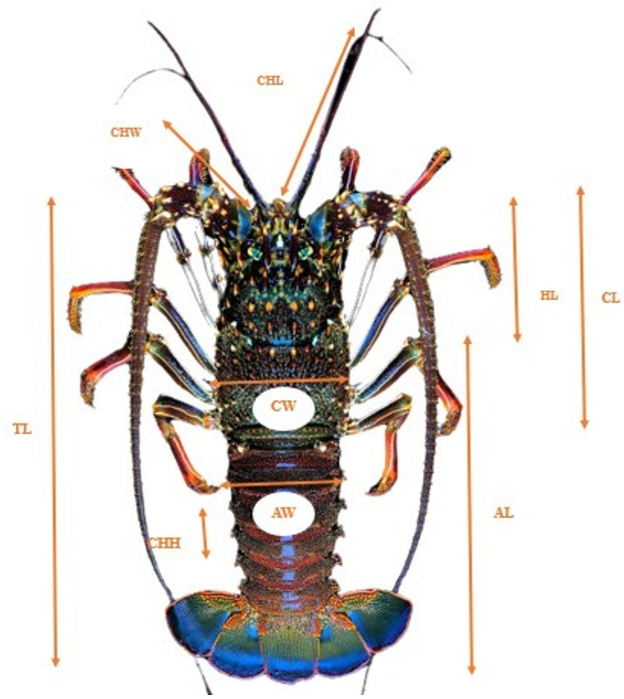

Fig. 4. Traditional Morphometric Method for *Panulirus spp* Lobsters

Table 2. Parameters for Traditional Morphometric Observation of Lobsters

Symbol	Information	Morphometric Character
TL	*Total Length*	Measurement from the tip of the rostrum to the tip
CL	*Carapace Length*	Measurement from the tip of the rostrum to the tip of the carapace
CW	*Carapace Width*	Measurement of the maximum width of the carapace on the dorsal side of the body
HL	*Cheliped Length*	Measurement from the base of the cheliped (claw) to the tip of the claw
CHH	*Abdomen Length*	Measurement of the length from the tip of the carapace to the tip of the telson
CHL	*Antenna Length*	Measurement of the length from the base of the antenna to the tip of the antenna
CHW	*Pereopod Length*	Measurement of the length from the base of the pereopod (abdominal leg) to its tip
AL	*Pleopod Length*	Measurement of the length from the base of the pleopod (abdominal fin) to its tip
AW	*Uropod Length)*	Measurement of the length from the base of the uropod (tail fin) to its tip

3 Result and Discussion

The ANOVA test indicates that the species' differences significantly influence the variation in morphological characteristics ($P < 0.05$) of both lobsters. Duncan's post hoc test revealed that four characteristics (Cheliped Length (HL), Pereopod Length (CHW), and Antenna Length (CHL)) differed significantly among species (Table 2).

In *P. penicillatus,* three characteristics are similar to *P. versicolor,* namely Cheliped Length (HL), Pereopod Length (CHW), and Antenna Length (CHL). This is based on the shape of HL, CHW, and CHL in both lobsters, which have similarities. The form of each segment of the lobster in morphometric truss measurements reveals a trapezium shape divided into four parts: the upper head, lower head, abdomen, and tail. In several segments, there are similarities, especially based on morphometric measurements forming triangles in each section.

In specific areas of each segment, there are similar sizes in lobster morphometrics. In the upper head section, parts A1 and A3 exhibit similarities; in the lower head section, there are similarities in B1 and B3; the abdomen section includes C1 and C3 similarities, and finally, the tail section shows similarities in D1 and D3.

The results of the Discriminant Function Analysis (DFA) on the truss morphometric characters divide the two lobster species in the waters of Sabang. The findings indicate an overlapping degree that signifies morphological similarity. Meanwhile, the morphological differences observed in lobsters are attributed to phenotypic changes influenced by the environment.

Moreover, in each segment, these similarities serve as markers for significant differences in lobster sizes, particularly between *P. penicillatus* and *P. versicolor.* While there are differences in length, the dimensions of each species within the same type have identical values, whereas those of different types exhibit significant differences. Another characteristic morphometric feature is the length of the antennae, with P. versicolor having longer antennae compared to the significantly shorter antennae of *P. penicillatus.* Additionally, *P. penicillatus* has a notably larger head with more defense mechanisms, especially in facing predators in the wild.

Table 3. Mean transformed values of morphometric characters in each lobster species. Values followed by different superscripts indicate significant differences ($p < 0.05$).

No.	Character (code)	Estimate Type Lobster	
		P. penicillatus	***P. versicolor***
1	Total Length *(TL)*	214,002 ± 67,8225[a]	195,692 ± 26,9264[a]
2	Carapace Length *(CL)*	69,954 ± 20,9053[a]	68,684 ± 12,9089[a]
3	Carapace Width *(CW)*	54,328 ± 14,5502[a]	55,914 ± 11,9376[a]
4	Cheliped Length *(HL)*	34,977 ± 10,4526[a]	27,474 ± 5,1618[b]
5	Pleopod Length *(AL)*	107,008 ± 33,9098[a]	117,414 ± 16,1554[b]
6	Uropod Length *(AW)*	44,328 ± 14,5502[a]	46,914 ± 11,9376[a]
7	Abdomen Length *(CHH)*	108,656 ± 29,1004[a]	111,828 ± 23,8752[a]
8	Pereopod Length *(CHW)*	20,496 ± 5,6155[a]	22,540 ± 3,2085[b]
9	Antenna Length *(CHL)*	99,854 ± 54,1513[a]	126,456 ± 26,3484[b]

The DFA analysis resulted in 1 function, which has an eigenvalue of 36.436, indicating that it accounts for 100% of the total variance. The morphological characteristics that contribute significantly among species are Cheliped Length (HL), Carapace Length (CL), Antenna Length (CHL), Pleopod Length (AL), and Total Length (TL) (Table 3).

Table 4. Eigenvalues, % variance, and structure matrix of Traditional Morphometric characters.

Function	**DF1**
Eigenvalue	36,436[a]
% of Variance	100,0
Canonical Correlation	0,987
Carapace Width (CW)[a]	0,082
Abdomen Length (CHH)[a]	0,082
Uropod Length (AW)[a]	0,082
Cheliped Length (HL)	-0,076
Pereopod Length (CHL)	0,052
Antenna Length (CHW)[a]	0,040
Pleopod Length (AL)	0,033
Total Length (TL)	-0,030
Carapace Length (CL)	-0,006

Table 5. of results of Eigenvalue Analysis on Morphometrics in Lobsters

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	27.595[a]	100.0	100.0	.982

Meanwhile, there is a significant difference in carapace length and total length between the two lobster species, especially in the total length of the captured lobsters. It was found that *P. penicillatus* has a larger total length compared to P. versicolor. In terms of weight, *P. penicillatus* is also heavier. The main factors underlying this are, firstly, the higher catch numbers of *P. penicillatus,* partly due to their more extensive habitat, and the capturing process of *P. penicillatus* is much easier. However, *P. penicillatus* can be more aggressive during the capture process.

The population of *P. penicillatus* in the waters of Sabang is significantly higher than that of P. versicolor. The abundant population results in larger sizes observed in *P. penicillatus* compared to P. versicolor. Another contributing factor is the feeding zone of the two lobsters. *P. penicillatus* has a feeding zone much closer to the shore than P. versicolor. Additionally, the dominance in lobster species corresponds to their respective habitats.

3.1 Truss Morphometrics in *P. versicolor* and *P. penicillatus*

The ANOVA results show that species differences affect Truss Morphometric characteristics ($P < 0.05$). Duncan's post hoc test revealed that five characteristics ([A1, A3], [B1, B3], [C5, C6], D4, [D5, D6]) differ significantly among species (Table 3). DFA analysis resulted in 1 function, which has an eigenvalue of 27.595, indicating that it accounts for 100% of the total variance. The morphological characteristics that contribute significantly among species are A1, B1, C5, A5, D5 (Table 5).

Table 6. Mean transformed values of truss morphometric characters in each lobster species. Values followed by different superscripts indicate significant differences ($p < 0.05$).

No	Character (Kode)	Estimate Type Lobster	
		P. penicillatus	*P. versicolor*
1	A1	34.977 ± 10.4526^a	27.474 ± 5.1618^b
2	A2	43.462 ± 11.6402^a	44.731 ± 9.5501^a
3	A3	34.977 ± 10.4526^a	27.474 ± 5.1618^b
4	A4	54.328 ± 14.5502^a	55.914 ± 11.9376^a
5	A5	50.524 ± 13.5348^a	50.323 ± 10.7438^a
6	A6	50.524 ± 13.5348^a	50.323 ± 10.7438^a
7	B1	34.977 ± 10.4526^a	41.210 ± 7.7454^b
8	B2	54.328 ± 14.5502^a	55.914 ± 11.9376^a
9	B3	34.977 ± 10.4526^a	41.210 ± 7.7454^b
10	B4	44.328 ± 14.5502^a	46.914 ± 11.9376^a
11	B5	49.436 ± 13.2354^a	50.323 ± 10.7438^a
12	B6	49.438 ± 13.2407^a	50.323 ± 10.7438^a
13	C1	74.906 ± 23.7368^a	82.196 ± 11.3161^a
14	C2	44.328 ± 14.5502^a	46.914 ± 11.9376^a
15	C3	74.906 ± 23.7368^a	82.196 ± 11.3161^a
16	C4	37.681 ± 12.3685^a	42.223 ± 10.7438^a
17	C5	65.914 ± 20.8940^a	78.080 ± 10.7400^b
18	C6	65.914 ± 20.8940^a	78.080 ± 10.7400^b
19	D1	32.102 ± 10.1729^a	32.106 ± 10.1759^a
20	D2	37.681 ± 12.3685^a	42.223 ± 10.7438^a
21	D3	32.102 ± 10.1729^a	32.106 ± 10.1759^a
22	D4	54.648 ± 17.9398^a	63.332 ± 16.1220^b
23	D5	43.710 ± 14.3462^a	53.832 ± 13.6963^b
24	D6	43.710 ± 14.3462^a	53.832 ± 13.6963^b

Tabel 7. *Eigenvalues*, *% variance*, dan *structure matrix* Character Truss Morphometric

Function	DF1
Eigenvalue	27,595[a]
% of Variance	100,0
Canonical Correlation	0,982
A1	**-0,088**
A3[a]	-0,088
C5	**0,070**
C6[a]	0,070
D5	**0,069**
D6[a]	0,069
B1	**0,065**
B3[a]	0,065
C1[a]	0,048
C3[a]	0,048
D4[a]	0,046
C4[a]	0,033
D2[a]	0,033
D1[a]	-0,021
D3[a]	-0,021
B4[a]	0,011
C2[a]	0,011
A4[a]	0,011
B2[a]	0,011
A2[a]	0,011
B5[a]	0,007
B6[a]	0,007
A6[a]	-0,002
A5	**-0,002**

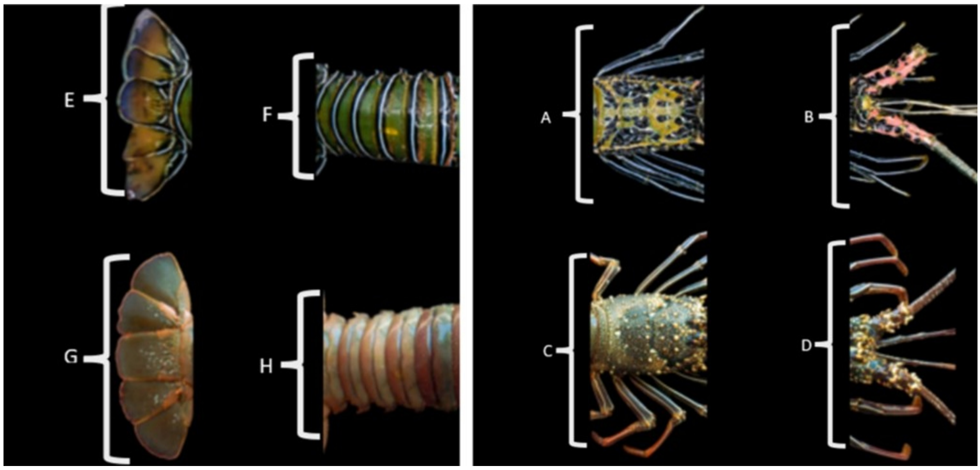

Fig. 5. illustrates the process of identifying the two most dominant lobster species in Sabang, namely *P. penicillatus* and *P. versicolor.* The comparison process focuses on the shapes of the upper head, lower head, abdomen, and tail.

4 Conclusion

In the waters of Sabang, it has been observed that there are morphological differences between the two lobster species, *P. penicillatus* and *P. versicolor.* These differences primarily pertain to the length of the antennae, the size of the claws, and the shape of the uropods. In the case of *P. penicillatus,* the body size is significantly larger when compared to P. versicolor. Physically, *P. penicillatus* holds an advantage in terms of habitat and food competition. As a result, *P. versicolor* tends to inhabit deeper waters.

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