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Reproductive Biology of Two Species Spiny Lobster in Donggala Waters Central Sulawesi

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Abstract. Spiny lobster species *Panulirus versicolor* and *P. femoristriga* in Donggala waters are reported to experience growth overfishing and recruitment overfishing. If this phenomenon continues, it will gradually reduce the spiny lobster population and result in an overall population decline. Information on reproductive biology is needed in the formulation of management and conservation policies for spiny lobsters in Donggala Waters, Central Sulawesi Province. The purpose of this study was to compare and analyze aspects of reproductive biology such as sex ratio, length-weight relationship, and spiny lobster condition factors. The research was conducted from July to December 2020 in the waters of Kabonga Village, Banawa Subdistrict, and Limboro Village, Central Banawa Subdistrict, Donggala District, Central Sulawesi Province. Reproductive biology data analysis applies several analytical models such as Chi-square, linear regression, Fulton condition factor, and Withney-Mann Test. The results showed no difference in sex ratio (balanced population) with negative allometric growth pattern and Fulton's condition factor in good condition (wellbeing) throughout the study in both *P. versicolor* and *P. femoristriga*. Population balance is important to ensure the continuity of recruitment, which is supported by adequate food availability, thus maintaining the stability of the spiny lobster population.

Keywords: Condition factor; Length-weight relationship; Sex ratio; Spiny lobster.

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INTRODUCTION

Spiny lobster resources are widely distributed in almost all Indonesian waters, including in the Makassar Strait which is one of the important areas for spiny lobster fishing (Musbir et al., 2018; Yunus & Parawansa, 2021). Among the spiny lobster fishing areas in the Makassar Strait, Donggala waters are one of the fishing bases, where there are two dominant types of spiny lobsters caught, namely stripe-leg spiny lobster (*Panulirus femoristriga*) and painted spiny lobster (*P. versicolor*) (Nurdin et al., 2023). Spiny lobster fisheries in Donggala waters are small-scale fisheries where the majority of fishers who catch spiny lobsters are traditional fishers (Setyanto et al., 2023) and the catch is collected by business actors involved in the supply chain, with the aim of being marketed as an export product (Mukminin et al., 2022; Priyambodo et al., 2020).

Spiny lobster species *P. versicolor* and *P. femoristriga* have contributed to the community's economy (Campo et al., 2023) because they have a high selling value, ranging from IDR 250,000 to IDR 450,000 per kilogram. The high selling value of spiny lobster encourages fishermen to conduct uncontrolled fishing (Boer et al., 2021) even though there are regulations related to spiny lobster fishing (Maskun et al., 2020). The impact of uncontrolled fishing has resulted in both spiny lobster species being reported as experiencing growth overfishing and recruitment overfishing (Nurdin et al., 2023). This indicates serious pressure on spiny lobster populations in these waters and concerns about their future sustainability (Mukhtar et al., 2021; Yonvitner et al., 2019).

Growth overfishing and recruitment overfishing occur in *P. femoristriga* and *P. versicolor* lobster species due to overexploitation of mature gonad and spawning phase lobsters (Nurdin et al., 2023). This condition can over time lead to a decrease in the number of recruits entering the spiny lobster stock, which will eventually lead to the depletion of the stock (Tirtadanu et al., 2022). This process, if allowed to continue, will gradually reduce the number of individuals entering the spiny lobster population, resulting in an overall population decline (Harahap et al., 2024; Zairion et al., 2023). This condition also has a direct impact on the aquatic ecosystem, as spiny lobsters have an important role in maintaining the balance of the ecosystem as natural predators and prey (Smith et al., 2023). Therefore, it is important to implement a sustainable management strategy to maintain the sustainability of the spiny lobster population.

In order to ensure the sustainability of spiny lobster resources in Donggala waters, it must be managed sustainably and to underlie it, research information is needed (Kembaren & Suman, 2023). Studies on spiny lobster species *P. femoristriga* and *P. versicolor* in Donggala waters have been carried out by Nurdin et al. (2023), but limited to stock status studies. There is no adequate information regarding the biological status of *P. femoristriga* and *P. versicolor* spiny lobsters in Donggala waters. Biological information is basic information in the management of spiny lobster resources. The biological information in question is the sex ratio (Indarjo et al., 2023; Jury et al., 2019), length-weight relationship (Mirzaei et al., 2023; Muzammil & Kurniadi, 2021), and condition factors (Asrial et al., 2020; Lawal-Are et al., 2018). Policy making based on research results will direct the management process toward the utilization of spiny lobster resources that are both economically valuable and ecologically sustainable (Damora et al., 2021; Tomi, 2019).

METHODS

Study Area

The research was conducted from July to December 2020 in the waters of Kabonga Village, Banawa Subdistrict, and Limboro Village, Central Banawa Subdistrict, Donggala District, Central Sulawesi Province (Figure 1). In this area, two species of spiny lobster are dominantly caught by fishermen, namely White-whiskered Coral Crayfish (*P. femoristriga*) and Painted spiny lobster (*P. versicolor*) (Nurdin et al., 2023). Specifically for *P. femoristriga*, it was the first record in Donggala Waters, Sulawesi in 2016 (Wahyudin et al., 2016).

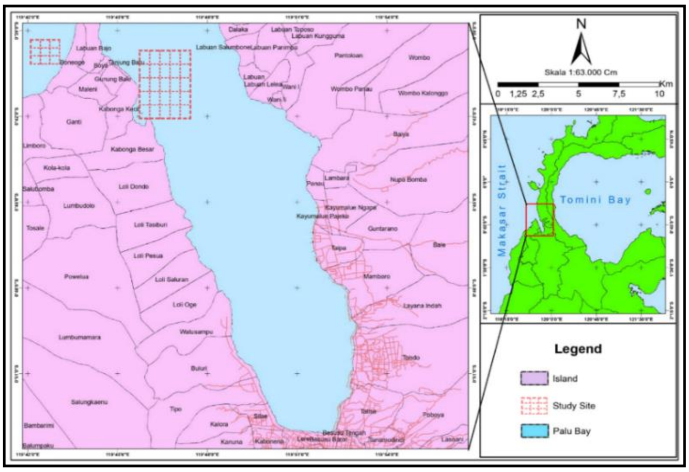

Figure 1. Fishing ground spiny lobster in Donggala Waters

Data Collection

Lobster samples were obtained from the catch of fishermen who dive at a depth of 5 - 8 m. The fishing activities were carried out at 8:00 pm. Fishing activities are carried out at night from 20.00 until dawn (03.00). Samples obtained were put into a cooler box with dimensions of 37 (length, cm) × 25 (width, cm) × 34.5 (height, cm) and given bulk ice to maintain the freshness of the spiny lobster. Sample analysis including sex ratio, length-weight relationship, and condition factor was conducted at the Water Quality and Aquatic Biology Laboratory, Faculty of Animal Husbandry and Fisheries, Tadulako University. The spiny lobster species sampled were *P. femoristriga* and *P. versicolor* (Figure 2). The total number of spiny lobster samples used for analysis of sex ratio, length-weight relationship, and condition factor was 200 spiny lobsters consisting of 86 *P. femoristriga* and 114 *P. versicolor*. Each spiny lobster sample was separated by species and each was measured for carapace weight and length.

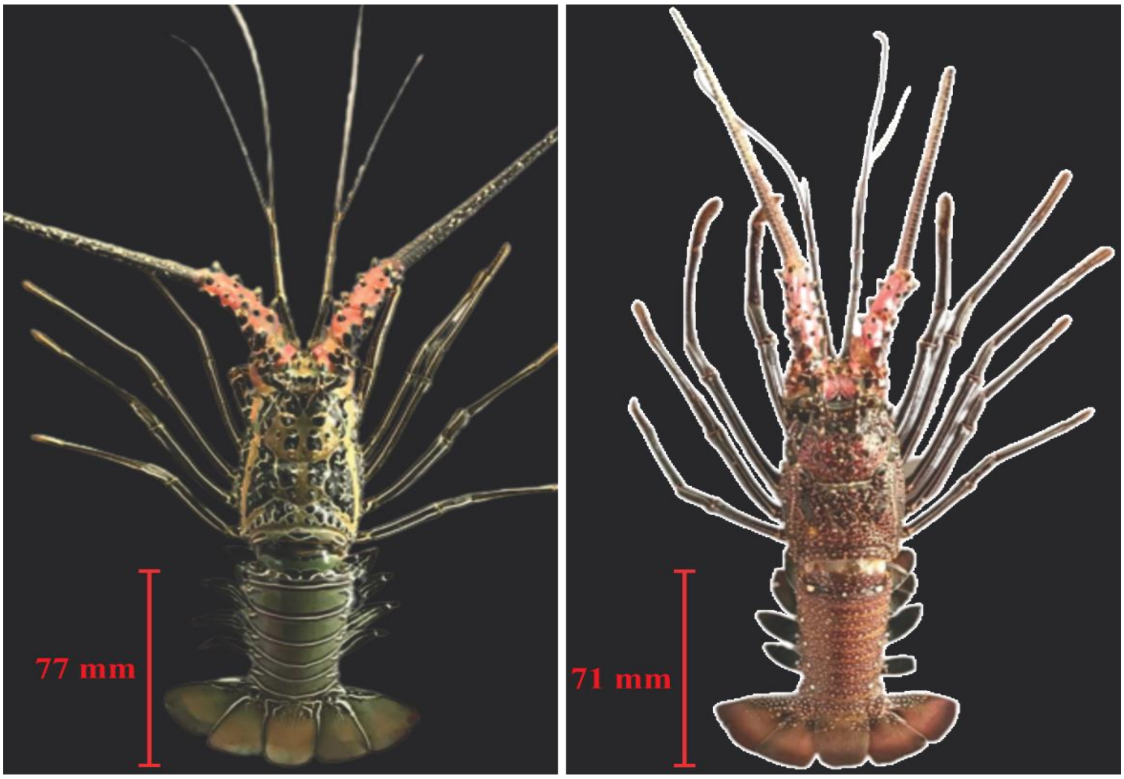

Figure 2. *Panulirus versicolor* (left) and *Panulirus femoristriga* (right)

Procedures

Carapace length was measured using a digital caliper with an accuracy of 0.1 mm while the weight was weighed using a digital scale with an accuracy of 0.1 g. Measurement of spiny lobster carapace length is carried out from the post-orbital end (near the eye) to the posterior end. The identification of spiny lobster sex follows the instructions of Radhakrishnan et al. (2015), namely the female spiny lobster is characterized by the presence of clear white protrusions (gonadophore) at both bases of the base of the third walking leg and has swimming legs (pleopod) each two sheets in pairs while the male spiny lobster is characterized by the location of the gonophore protrusion at the base of the fifth oval-shaped walking leg, and the swimming legs (pleopod) each consist of only one sheet.

Data Analysis

Differences in sex ratios of male and female spiny lobsters were analyzed using the Chi-Square test (Zar, 2010) as follows:

$$x^2 = \sum_{i=1} \frac{(Oi - Ei)^2}{Ei}$$

Where Oi refers to the value of observation, Ei refers to the value of expectations.

The spiny lobster length-weight relationship was calculated using a classical equation (Falsone et al., 2022) as follows:

$$W = aCL^b$$

Where W is the spiny lobster weight (g), CL is carapace length (mm); a is Intercept (the intersection of the weight-length relationship curve with the y-axis); b is Slope. If the value of b = 3 means that the spiny lobster has an isometric growth pattern, otherwise if b ≠ 3 means that the spiny lobster growth pattern is allometric.

The relative weight condition factor (Wr) and the Fulton condition factor coefficient (K) are used to evaluate the condition factor of each individual. The relative weight condition factor (Wr) is determined based on the equation of Black et al. (2021) as follows:

$$Wr = \frac{W}{Ws} \times 100$$

Wr is the relative weight, W is the weight of each spiny lobster, and Ws is the predicted standardized weight of the same sample as calculated from the combined regression of the length of the weights through the distance between species by Equation:

$$Ws = aCL^b$$

A relative condition factor of <100 indicates a problem in food availability and >100 indicates a food surplus (Haser et al., 2022).
The condition factor was calculated using the Fulton equation (Froese, 2006).

$$F = \frac{W}{aCL^b}$$

Where CF is the condition factor; W is spiny lobster weight (g); L is carapace length (mm); and a and b are constants obtained from regression.
The mean difference in condition factor between male and female spiny lobsters was used in the Withney-Mann Test (Wilks, 2020):

$$Z = \frac{U - \frac{n1n2}{2}}{\sqrt{\frac{n1n2(n1+n2+1)}{12}}}$$

Where Z is the test statistic; U is the smallest value between U1 and U2; n1 and n2 are the number of samples. All analyses were performed using R software version 4.3.2.

RESULTS AND DISCUSSION

Sex Ratio

The results of the analysis of the sex ratio of spiny lobster caught in Donggala waters are 47% male 53% female (1:1.12) for *P. versicolor* and 45% male 55% female (1:1.22) for *P. femoristriga* (Figure 3). The results of the Chi-Square analysis showed the ratio between male and female sexes respectively χ^2=5.509; df=1; p>0.05 and χ^2=0.531; df=1; p>0.05) all are not significantly different or the male and female populations are balanced for both *P. versicolor* and *P. femoristriga* species. This indicates that the population of both species of spiny lobster is in an ideal condition to maintain its population.

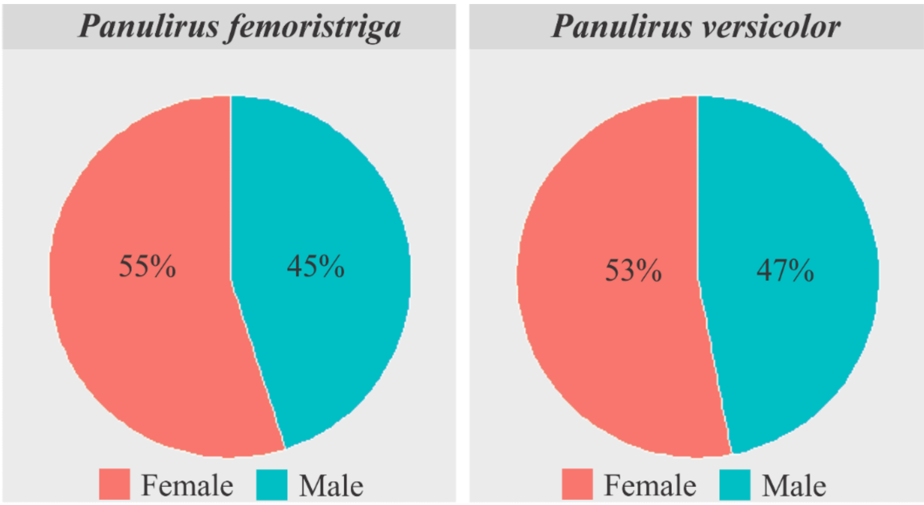

Figure 3. Sex ratio of spiny lobster in Donggala Waters

Sex ratio, length-weight relationship, and condition factors are used as guidelines to determine the condition of spiny lobsters, including population balance, reproductive potential, obesity level, health level, productivity, and physiological conditions of lobsters in nature (Dinh et al., 2020; Li et al., 2023; Ragheb, 2023). In this study, the population ratio of *P. versicolor* and *P. femoristriga* males and females in ideal conditions is 1: 1 and in all size groups, male and female spiny lobsters are always balanced in population. Most studies on the sex ratio of spiny lobsters in Indonesia reveal that the male and female populations are relatively balanced as in the species *P. versicolor* in Latuhalat Waters of Ambon (Ongkers et al., 2014), *P. homarus* in Lampung Province Waters (Zairion et al., 2023). Similar things were also found in 4 species of spiny lobster in the Madura Strait (*P. versicolor*, *P. homarus*, *P. ornatus*, and *P. polyphagus*) (Setyanto et al., 2021).

An unbalanced sex ratio between male and female individuals has a serious impact on the sustainability of spiny lobster populations from both an ecological and economic perspective (Koepper et al., 2021; Morán et al., 2016). In the context of reproduction, population balance ensures that each female has an equal chance of egg fertilization by spermatozoa from individual males (Atherley et al., 2021; Haryono et al., 2021). This balance is key to ensuring the recruitment process continues, which in turn supports the sustainability of the spiny lobster population in its natural habitat (Asrial et al., 2020; Yonvitner et al., 2019). Therefore, maintaining a 1:1 sex ratio in *P. versicolor* and *P. femoristriga* in Donggala Waters is imperative so that the population is maintained for future generations.

Lobster Wellbeing

Based on the results of regression analysis of the relationship between carapace length and spiny lobster weight, the respective equations were obtained $W=0.1792CL^{2.9416}$ ($R^2=0.9229$) male and $W=0.2598CL^{2.7229}$ ($R^2=0.8745$) females for *P. versicolor* while for *P. femoristriga* the equation is obtained $W=0.2728CL^{2.9599}$ ($R^2=0.5217$) male and $W=0.4289CL^{2.0056}$ female ($R^2=0.7541$) (Table 1). The results of the t-test on the value of b in the four regression equations were significantly different at the 95% confidence level so the spiny lobster growth pattern is allometrically negative (b<3), which is an unbalanced ratio of growth velocity between carapace length and body weight. The value of b spiny lobster ranged from 2.0056 - 2.9599, where the smallest b value was in female *P. femoristriga*.

Table 1. Spiny lobster length-weight relationship

Species	Sexes	Formula	R^2	Growth Pattern
P. versicolor	Male	$W=0.1792CL^{2.9416}$	0.9229	Allometric negative
	Female	$W=0.2598CL^{2.7229}$	0.8745	Allometric negative
P. femoristriga	Male	$W=0.2728CL^{2.9599}$	0.5217	Allometric negative
	Female	$W=0.4289CL^{2.0056}$	0.7541	Allometric negative

The average condition factor of male and female lobsters caught in Donggala Waters ranged from 1.0112 ± 0.1514, 1.0258 ± 0.2492, 1.1302 ± 0.6733, and 1.0151 ± 0.1794 respectively (Figure 4) and the relative weight condition factors were all >100. The results of the Withney-Mann Test showed that the mean condition factors between males and females caught in both *P. versicolor* and *P. femoristriga* were not significantly different ($p>0.05$). The average condition factor of male spiny lobsters was the same as female spiny lobsters, indicating that the condition of male and female spiny lobsters was the same throughout the study.

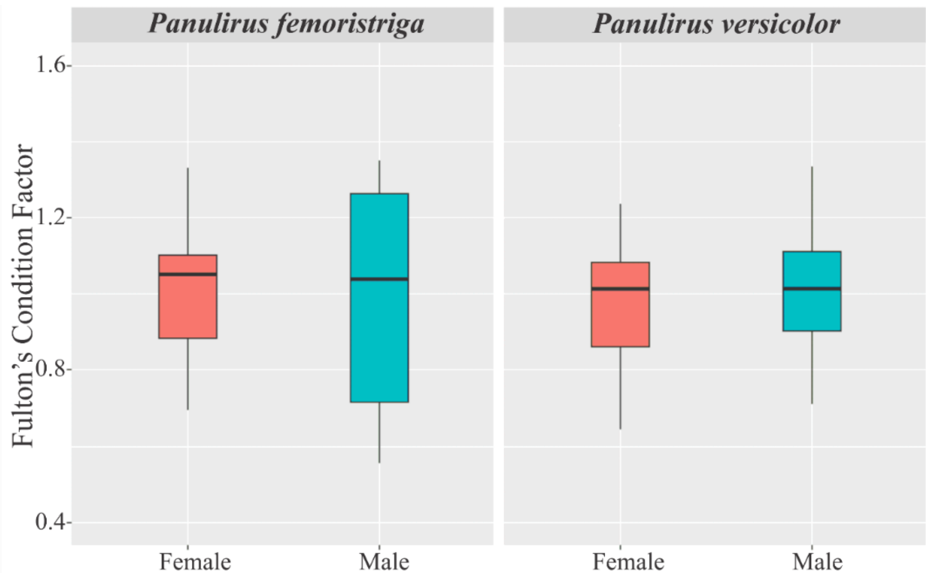

Figure 4. Condition factor of spiny lobster

The b value of spiny lobster in Donggala Waters ranges from 2.0056 - 2.9599 indicating a negative allometric growth pattern. Several studies have shown that spiny lobster growth patterns tend to be the same in each water body except for male *P. versicolor* in Latuhalat Ambon Waters and female *P. versicolor* in Tanjung Kasuari, West Papua (Table 2) (Ongkers et al., 2014; Situmorang et al., 2021). Muzammil & Kurniadi (2021) researched the Sebatik Island Waters on spiny lobster species *P. ornatus* and found a negative allometric growth pattern (b = 2.8573 and 2.7747). Other lobster species such as *P. homarus* caught in Lampung Province Waters also have negative allometric growth patterns (b = 1.4260 and b = 1.4479) (Zairion et al., 2023). Tomi (2019), conducted research on the length-weight relationship of spiny lobster species *P. homarus* in Palabuhanratu Waters and also found a negative allometric growth pattern (b = 2.0612 and b = 2.0651).

Table 2. Spiny lobster growth patterns in several waters in indonesia

Location	Species	Sex	b	Growth Pattern	Source
Latuhalat Waters	*P. versicolor*	M	2.0482	NA	Ongkers et al. (2014)
		F	2.9037	IS	
Palabuhanratu Waters	*P. homarus*	M	2.0612	NA	Tomi (2019)
		F	2.0651	NA	
Labangka Tidal Waters	*P. homarus*	B	1.108	NA	Asrial et al. (2020)
	P. penicillatus	B	2.422	NA	
Sebatik Island Waters	*P. ornatus*	M	2.5770	NA	Muzammil & Kurniadi (2021)
		F	2.7747	NA	
Madura Strait	*P. homarus*	B	1.4236	NA	Setyanto et al. (2021)
	P. ornatus	B	1.7456	NA	
	P. versicolor	B	2.9128	IS	
Tanjung Kasuari, West Papua	*P. versicolor*	M	2.7302	NA	Situmorang et al. (2021)
		F	2.9349	IS	
Makbon, Sorong	*P. versicolor*	M	2.8884	NA	
		F	2.8617	NA	
Lampung Province Waters	*P. homarus*	M	1.4260	NA	Zairion et al. (2023)
		F	1.4479	NA	
Simeulue Island	*P. versicolor*	B	2.3900	NA	Harahap et al. (2024)
Donggala Waters	*P. versicolor*	M	2.9416	NA	This research
		F	2.7229	NA	
	P. femoristriga	M	2.9599	NA	
		F	2.0056	NA	

Note: M = Male; F = Female; NA = Negative Allometric; B = Male + Female; and IS = Isometric

Negative allometric growth patterns in lobsters in various Indonesian waters, both of the same and different species, show similar patterns, most of which are thought to be influenced by high fishing activity (Segun et al., 2022). This finding has been confirmed by several studies, such as in *P. penicillatus* and *P. homarus* in the Labangka Tidal Waters, where the exploitation rate has passed the optimum limit (overexploitation) (Asrial et al., 2020). Similar conditions occurred in *P. homarus* species caught in Palabuhanratu Waters, where the fishing mortality rate was very high with the exploitation rate reaching E = 0.59 for males and 0.61 for females (overexploitation) (Tomi, 2019). Meanwhile, in *P. versicolor* and *P. femoristriga* in Donggala Waters, research by Nurdin et al. (2023) reported that the Spawning Potential Ratio (SPR) value in both species was below the biological limit reference point value, with SPR values of 11% and 17% respectively, indicating that *P. femoristriga* and *P. versicolor* have experienced overfishing.

Fulton's condition factor in *P. versicolor* and *P. femoristriga* males and females were relatively the same throughout the study, where Fulton's condition factor was >1. This value is ideal for spiny lobster growth and reproduction (Noori et al., 2015; Situmorang et al., 2021). Furthermore, the Fulton's condition factor value of male *P. femoristriga* in Donggala Waters is higher than the Fulton's condition factor value of spiny lobsters in several Indonesian waters (Table 3). In comparison, the lowest Fulton's condition factor values were found in *P. homarus* and *P. penicillatus* in Labangka Tidal Waters (Asrial et al., 2020).

Table 3. Fulton's condition factor of spiny lobster in several waters in Indonesia

Location	Species	Sexes	Fulton's condition factor		Source
			Range	Mean	
Labangka Tidal Waters	*P. homarus*	B	0.0320-0.1100	-	Asrial et al. (2020)
	P. penicillatus	B	0.0340-0.1270	-	
Tanjung Kasuari, West Papua	*P. versicolor*	M	0.7439-1.7460	1.0049	Situmorang et al. (2021)
		F	0.6484-1.2345	0.9865	
Makbon, Sorong	*P. versicolor*	M	0.8132-1.2430	0.9948	
		F	0.6407-1.8861	0.9875	
Donggala Waters	*P. versicolor*	M	0.7107-1.3340	1.0112	This Study
		F	0.6445-1.9000	1.0258	
	P. femoristriga	M	0.5532-2.5272	1.1302	
		F	0.6935-1.3295	1.0151	

Note: M = Male; F = Female; and Both = Male + Female

The value of the spiny lobster relative condition factor which is >100, indicates that the availability of food for spiny lobsters is still sufficient in Donggala Waters. Food availability plays a key role in lobster growth (Achmad et al., 2023; Talbot et al., 2019). Lobsters can utilize various types of food sources, not only eating marine life such as bivalves, gastropods, barnacles, and crustaceans, but also consuming detritus, plants, and various other marine organisms (Amin et al., 2022; Masithah et al., 2023; Smith et al., 2023). These spiny lobster food preferences are still well met in Donggala Waters, reflecting the sustainability of food resources in the marine environment.

The three models (sex ratio, length-weight relationship, and Fulton condition factor) are important foundations for designing effective conservation policies in the future. However, they are not sufficient to predict the complex behavior of lobster populations, which are influenced by various environmental factors. Therefore, effective conservation policies must combine model results with an in-depth understanding of environmental dynamics. Only with a holistic approach that considers these factors can the sustainability of the spiny lobster population in Donggala Waters be assured. Thus, conservation efforts will be more efficient and have a positive impact on the local ecosystem.

CONCLUSION

There are no differences in sex ratio, length-weight relationship, and condition factors of *P. versicolor* and *P. femoristriga* in Donggala Waters. Male and female spiny lobster populations are balanced with negative allometric growth patterns and the same condition factors throughout the study. Population balance is key to ensure the recruitment process continues. While the negative allometric growth pattern is thought to be influenced by the high level of fishing activity, Fulton's condition factor shows the spiny lobster is in good condition (well-being). This condition is supported by adequate food availability, which also plays a role in supporting the stability of the spiny lobster population. Further studies on biological such as reproduction (peak spawning), reproductive potential, and spawning aggregation sites need to be done for the effectiveness of lobster management in the Donggala Waters.

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