Biological aspect of double-spined rock lobster (*Panulirus penicillatus*) in Wonogiri Regency waters, Central Java, Indonesia

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Abstract. Spiny lobsters (*Panulirus* spp.) are an economically important species in the fishery industry and continuously being exploited, particularly in the South of Java. Lobsters in Wonogiri Regency waters have decreased in number, and the average size lobsters caught is also getting smaller. Double-spined rock lobster (*Panulirus penicillatus*) is the dominant species caught by the fishermen but has limited biological information. The objective of this study is to identify several factors affecting double-spined rock lobster (*P. penicillatus*) population in terms of growth parameters, mortality rates, and exploitation rates. This study was conducted in August 2018-January 2019. The analysis uses the FAO-ICLARM Stock Assessment Tool (FISAT II) program. The growth rates (K) of *P. penicillatus* male and female lobsters are 0.32 year\(^{-1}\) and 0.37 year\(^{-1}\). The mortality rates (Z) 2.35 year\(^{-1}\) for males and 2.84 year\(^{-1}\) for females. The exploitation rate of males and females are 0.77 and 0.78, respectively. It has exceeded the optimal level (0.5) and reached overfishing value. The management of lobster fisheries needs to be done by several approaches, including a reduction of fishing efforts and prohibited from catching lobster in berry (with eggs) conditions to sustain their population naturally.

1. Introduction
Spiny lobsters (*Panulirus* spp.) are an economically important species in the fishing industry and continue to be exploited, especially in the southern waters of Java, Indonesia. The distribution of spiny lobsters in the southern waters of Java starts from the Sunda Strait, Binuang, Palabuhanratu, Pangandaran, Cilacap, Kebumen, Gunungkidul, to Pacitan [1]. Gunungkidul Regency and Pacitan Regency waters as the center of lobster distribution area in southern Java is separated by Wonogiri waters. The fishery in southern Java catches six species of *Panulirus*, with the majority being *Panulirus homarus* and *P. penicillatus* [2]. Of those species, *P. penicillatus* is the prevalent species caught in Wonogiri waters [3]. The high demand for lobsters will increase the number of lobster fishermen and efforts in lobsters fishing, especially in lobster distribution areas, such as the Wonogiri...
Regency waters. Increased lobster fishing activities can reduce the lobster population quickly if done through irresponsible fisheries.

Some studies indicate the rate of exploitation (E) of lobster in several WPP NRI 573 locations were already overexploited, such as Palabuhanratu waters [1, 4] and Gunungkidul waters [5]. The rate of lobster exploitation (E) in Wonogiri waters is stated in overfishing conditions in 2004 and 2014, both in biological and economic aspects [3, 6]. Although the rate of lobster exploitation in Wonogiri waters already overfishing, lobsters fishing activities in this location continuing and also becoming fishing ground for other fishers next to Wonogiri Regency, such as DI Yogyakarta, Pacitan, and even Banyuwangi fishers put Wonogiri waters as their fishing ground. Those fishers are more modern than local fishers because they are using the boat to do the fishing operation. Other issues are lobsters fishing conducted by the part-time artisanal fishers from coastal cliffs who use krendet (hoop-nets) are currently unrecorded, and there is reluctance by fishers to release small lobsters and those in berry (with eggs).

To manage lobster fisheries resources and sustainability exploitation in Wonogiri waters, it needs biological information about lobsters captured in Wonogiri waters. This research aims to analyze the biological aspect of double-spined rock lobster (P. penicillatus) in Wonogiri waters, consists of sex ratio, length-weight analysis, growth parameter, and level of exploitation (natural mortality rate, fishing mortality rate, and total mortality rate). The output of this research, hopefully, can be used as basic information in formulating lobster management policies in Wonogiri waters.

Crustacean resources have been interesting objects of research for a long time; however, research in the sea waters of Wonogiri Regency waters has not been done much. Crustacean resource studies include research on mantis shrimp [7-10], swimming crabs or blue swimming crabs [11-13], and sea retreats [14-20]. Research related to lobster (Panulirus spp.) that have been conducted include aspects of lobster biology [21, 22], captured [5, 23], stock assessment [4, 24, 25], and socioeconomic aspects [26-29].

2. Method

2.1. Data collection and morphometric measurements of lobsters

The sea fishery in Wonogiri Regency occurs along the southern Wonogiri Regency area, Central Java Province. The main lobster fishing activities in Wonogiri Regency centralized in three villages at Paranggupito district; they are Paranggupito village, Gudangharjo village, and Gunturharjo village. Six surveys of lobster fishers were conducted from August 2018 until January 2019. Lobsters were identified, sexed, weighed (g) and measured the carapace length (mm). Samples were collected from fishers who have the fishing based on those three villages. The average seawater temperature was 29°C during the sampling period. The research location is, as shown in Figure 1.

In total, 773 samples (all kinds of lobsters) were collected from the Paranggupito district simultaneously, and krendet (trap net) was used to catch lobsters. Krendet is a passive fishing gear used by fishers in Wonogiri waters to catch lobsters. This trap net is put on rocky water by throwing this krendet from the top of the cliff. The carapace length of each sample was measured from the edge of the orbit to the posterior to the end of the carapace using a calliper (mm), and weight using digital scales (± 1 g).
2.2. Data analysis

2.2.1. Sex Ratio. Sex ratio is important to see the comparison of each of the sexes of lobsters found in Wonogiri Regency waters. Sex ratio is the ratio between the number of male lobsters and females obtained from the proportion of catches during the sampling period. Sex ratio is calculated using the formula:

\[ SR = \frac{nM}{nF} \]

Remarks:
SR = Sex Ratio
nM = Sample size of male lobsters
nF = Sample size of female lobsters

2.2.2. Length of weight analysis. Growth patterns can be seen by linking length growth and weight growth. Analysis of the relationship between lobster length weights using the formula [30] as follows:

\[ W = aL^b \]

W is the weight of lobster (g), L is the carapace length (mm), a and b are the weight growth coefficient. The relationship of length and weight can be interpreted through the value of b (as an estimator of \( \beta \) the level of closeness of the relationship between the two parameters) with the hypothesis:
1. \( H_0: \beta = 3 \), has an isometric relationship (growth pattern of weights comparable to long growth patterns)
2. \( H_0: \beta \neq 3 \), has an allometric relationship (weight growth patterns are not proportional to the long growth pattern).
There are two kinds of allometric growth patterns, positive allometric (b > 3) and negative allometric (b < 3). Positive allometric indicates the growth of dominant weight compared to length, while negative allometric indicates that long growth is more dominant than growth in weight.

2.2.3. Growth parameters (K and CL∞). Growth parameters (K and CL∞) determined by the ELEFAN I [31] method is based on the von Bertalanffy equation as follows:

\[ CL_t = CL_{\infty} (1 - e^{-K(t - t_0)}) \]

Lt is the carapace length at age t; CL∞ is the asymptotic length of carapace length when reaching t years old; K is growth coefficient; t is lobster age, and t₀ is theoretical age when the length of carapace is zero.

2.2.4. Mortality rates and exploitation rates. Mortality rates and exploitation rates are calculated using the FISAT II program. The natural mortality rate (M) is calculated using equation [32] with an average temperature of 29 °C as follows:

\[ \log M = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log K + 0.463 \log T \]

The estimation of catching mortality mark (F) was calculated using the following equation F = Z - M, and the rate of exploitation (E) was obtained from fishing mortality rate (F) and total mortality rate (Z).

\[ E = \frac{F}{F+M} = \frac{F}{Z} \]

M is natural mortality, F is fishing mortality, and Z is total mortality. E > 0.5 represents high exploitation (overfishing); E < 0.5 represents low exploitation (under fishing) and E = 0.5 shows optimal fishing levels [33].

3. Results and Discussions

3.1. Variety of lobsters

In Indonesian waters, there are seven kinds of panulirus lobsters; they are P. homarus, P. penicillatus, P. longipes, P. polyphagus, P. versicolor, P. ornatus, and P. femoristriga [1]. Lobsters live in areas with characteristics of rocky sand beaches [34] and on coral reefs [35]. Lobster caught in Wonogiri Regency waters consists of three kinds of lobster, they are double spinned rock lobster (P. penicillatus), sand lobster (P. homarus), and ornate rock lobsters (P. ornatus). The total sample obtained in this study was 773, consisting of 677 double spinned rock lobster P. penicillatus (87.28%), 68 sand lobsters P. homarus (9.01%), and 28 ornate rock lobsters P. ornatus (3.71%) as in Figure 2.

![Figure 2](image1)  Variety of lobsters caught in Wonogiri Regency waters during the study.

![Figure 3](image2)  The varieties of lobsters catch in Wonogiri Regency water.
Figure 4. Paranggupito district rainfall in the year 2011-2018 [36, 37].

The lobster catches vary from October, from the beginning it only consisted of one species, namely double-spined rock lobster during sampling in August and September to three kinds starting in October as in Figure 3. The emergence of various types of catches can be caused by the start of increasing rainfall in the Wonogiri Regency. Based on rainfall data, it is known that there was an increase in rainfall from October to February, as shown in Figure 4.

3.2. Sex ratio and length frequency distribution

A total number of 677 double-spined rock lobster *P. penicillatus* (389 males and 288 females) were successfully recorded from the Paranggupito district, Wonogiri Regency, in percentage 57.46% for male and 42.54% for female. The sex ratio of males and females of lobsters’ population in this research shows 1.35:1. Combination of male and female carapace length ranged between 57.0-124.0 mm with a dominant range between 73.0-76.0 mm. Male lobster carapace length ranged between 57.0-124.0 mm, and females ranged between 65.0-109.0 mm (Figure 5).

(a) male  
(b) female

Figure 5. Carapace length-frequency distribution of double-spined rock lobster (*P. penicillatus*) during the sampling period in Wonogiri waters.

Based on research results, it is known that double-spined rock lobster male has longer carapace than female. This is due to factors that influence lobster growth, including biological and ecological factors. Although the double-spined rock lobster is in the same habitat and ecological factors, they have different biological factors. The biological factors of lobster include sex, genetics, level of sex maturity, growth phase, and eating habits [38, 39].

According to the Regulation of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 56 of 2016, lobsters fishing (*Panulirus* spp.) is permitted with a carapace length of more than 8 cm or weighing more than 200 g. This means that of the 677 *P. penicillatus* lobster samples, 317 or 48.31% of the samples have carapace lengths below 8 cm or are still below the allowable catch size, while 360 or 51.69% of the samples have carapace lengths above 8 cm or above the size allowed to be caught under these regulations. Furthermore, based on the individual weights of
lobster, there are 218 samples or 32.08% have weights below 200 g, and 459 samples or 67.92% have weights above 200 g (Figure 6). The number of lobsters in accordance with the regulations based on individual weight is higher than carapace length. Therefore, this research data is useful in supporting lobster resource management strategies, including optimal catch strategies to maintain species sustainability and economic benefits.

Figure 6. Distribution of lobster size based on carapace length (a) and individual weight (b) *P. penicillatus* for the period August 2018 - January 2019 in Wonogiri Regency waters.

3.3. Length-weight relationships double spined-rock lobster (*P. penicillatus*)

Length-weight relationships between carapace length and weight of double spined rock lobster (*P. penicillatus*) were carried out to determine growth patterns that were analyzed using regression analysis. The relationship between carapace length and body weight of male lobster is \( \text{W} = 0.0087\text{CL}^{2.3233} \) with an \( R^2 \) value of 88.61\% and female \( \text{W} = 0.0051\text{CL}^{2.4262} \) with an \( R^2 \) value of 82.36\%. As for the relationship between carapace length and body weight of lobster (*P. penicillatus*) combined male and female is \( \text{W} = 0.0062\text{CL}^{2.3931} \) with a value of \( R^2 \) 86.12\%. The length-weight relationship of double-spined rock lobster at the study location is as shown in Figure 7.

![Figure 7. Length-weight relationship of *P. Penicillatus* (a) male; (b) female.](image)

The \( b \) value for male lobsters is 2.3233, and the female \( b \) value is 2.4262. T-test was carried out on male and female lobsters; the results showed that \( b \neq 3 \), so it can be concluded included in the negative allometric category which means that the length of lobster both male and female is faster than weight gain. The double spined rock lobster growth pattern (*P. penicillatus*) in Wonogiri Regency waters is the same as in other areas, such as in Gunungkidul and Pacitan Regency waters, and in the waters of Simeuleu Regency (Table 1).
Table 1. Growth coefficient (b) *P. Penicillatus* in several Indonesian water locations.

| Locations      | Sex          | b    | Growth pattern       | Reference   |
|----------------|--------------|------|----------------------|-------------|
| Wonogiri       | Male         | 2.3190 | Negative allometric  | This study  |
|                | Female       | 2.3430 | Negative allometric  |             |
|                | Combined     | 2.3440 | Negative allometric  |             |
| Simeuleu       | Combined     | 2.571  | Negative allometric  | [41]        |
| Wonogiri       | Male         | 2.68   | Negative allometric  | [6]         |
|                | Female       | 2.59   | Negative allometric  |             |
| Gungungkidul   | Male         | 2.7559 | Negative allometric  | [21]        |
| and Pacitan    | Female       | 2.8884 | Negative allometric  |             |
|                | Combined     | 2.8287 | Negative allometric  |             |

3.4. Growth parameter (K and $CL_{\infty}$)

Estimation of growth parameters of double spined rock lobster (*P. penicillatus*) uses the von Bertalanffy equation with carapace length-frequency data as input data in the ELEFAN I (Electronic Length Frequency Analysis) analysis contained in the FISAT II program. The growth coefficient (K) value for female rock lobsters is 0.37 year$^{-1}$ higher than male rock lobsters which are only 0.32 year$^{-1}$. Whereas the asymptotic carapace length ($CL_{\infty}$) of female rock lobster is only 133.75 mm, slightly shorter than male rock lobster which can reach 142.00 mm. These values are still higher compared to research conducted in the same waters in 2014 that the estimated results of the growth coefficient of male lobsters were only 0.15 years$^{-1}$ and female rock lobsters 0.19 years$^{-1}$. The asymptotic carapace length ($CL_{\infty}$) of male lobsters is 136 mm, and female lobster is 123 mm [5]. In general, female lobsters experience faster growth than male lobsters. A comparison of growth coefficient (K) and asymptotic carapace length ($CL_{\infty}$) of rock lobster in several Indonesian water locations are shown in Table 2.

Table 2. Growth coefficient (K) and asymptotic carapace length ($CL_{\infty}$) *P. penicillatus* in Wonogiri and Palabuhanratu waters.

| Location       | Sex   | K    | $CL_{\infty}$ | Reference |
|----------------|-------|------|--------------|-----------|
| Wonogiri       | Male  | 0.32 | 142.00       | This study|
|                | Female| 0.37 | 133.75       | This study|
|                | Male  | 0.15 | 136          | [6]       |
|                | Female| 0.19 | 123          |           |
| Palabuhanratu  | Male  | 0.36 | 122.0        | [40]      |
|                | female| 0.41 | 120.4        |           |

In general, the growth rates of lobsters belonging to the Palinuridae family range between 0.27-0.54 year$^{-1}$. Asymptotic carapace length varies in value, but in general, is in the range 118-164 mm [42-44]. Different $CL_{\infty}$ values are only estimated for lobsters at that location. Likewise, the growth coefficient (K) often has significant differences. Differences in location can cause differences in growth patterns, even with the same species. This difference can be caused by ecological and biological factors. These ecological factors include seasonality and water quality (temperature, salinity, and pH), geographical position and sampling techniques. Whereas biological factors, including gender, gonad development, growth phase and eating habits [38]. The growth coefficient (K) value of rock lobster less than 1 indicates that this species has slow growth [33]. This means that this species needs more time to grow to reach a standard size of consumption or commercial size.

3.5. The mortality rate and exploitation rate

Many factors in the marine environment can influence the likelihood of individual lobsters surviving in a population. Unfavourable conditions include lack of food, competition, and predation. The results of the analysis showed that the natural mortality of male and female double-spined rock lobster was
0.55 and 0.62, respectively, smaller than the mortality due to fishing 1.80 and 2.22 (Figure 8). This shows that the rate of mortality of double-spined rock lobsters in Wonogiri waters is greater due to fishing (F). Fishing mortality rate (F) of male and female lobster is higher than its natural mortality rate. The total mortality of female lobsters is higher than the total mortality of male lobster; this indicates that female lobster stocks are more susceptible to death than male lobsters.

![Catch curve as the determinant of mortality rate of double spined rock lobster P. penicillatus in Wonogiri Regency waters (a) male and (b) female.](image)

Figure 8. Catch curve as the determinant of mortality rate of double spined rock lobster *P. penicillatus* in Wonogiri Regency waters (a) male and (b) female.

This condition also occurs in several water locations in Indonesia. Factors affecting the level of exploitation in Palabuhanratu are fishing activities as in Table 3. This study confirms the impact of exploitation rates on the high lobster mortality rate, which generally occurs in Indonesia, especially for double -spined rock lobster (*P. penicillatus*).

**Table 3. Double-spined rock lobster (*P. penicillatus*) rate of exploitation in Wonogiri and Palabuhanratu waters.**

| Location       | Sex   | M     | F     | Z     | E     | Reference |
|----------------|-------|-------|-------|-------|-------|-----------|
| Wonogiri       | Male  | 0.55  | 1.80  | 2.35  | 0.77  | This study|
|                | Female| 0.63  | 2.21  | 2.84  | 0.78  |           |
| Palabuhanratu  | Male  | 0.62  | 0.74  | 1.36  | 0.54  | [40]      |
|                | Female| 0.68  | 1.69  | 2.37  | 0.71  |           |

Exploitation rate (E) of male and female lobsters at the study sites respectively reached 0.77 and 0.78. This shows that the rate of exploitation (E) of double spined rock lobster in Wonogiri Regency waters has experienced overfishing. According to [32], to ensure sustainability, the level of exploitation of fisheries stocks is recommended around 0.5 (E opt. = 0.5). The use of E = 0.5 as the optimal value for the level of exploitation is based on the assumption that fishing mortality and natural mortality are in a balanced condition (F = M). Fishing can be said at optimal conditions if the rate of exploitation (E) = 0.5, if E > 0.5 can indicate overexploitation has occurred (overfishing), while the value of E < 0.5 indicates the level of exploitation is low (underfishing).

3.6. Substrate characteristic

Based on the results of substrate texture analysis at six observation stations, namely Sembukan (P-1 to P-3) and Nampu (P-4 to P-6), the highest percentage of fractions is found in the type of sand. Percentage values of dominant sand fractions with values of more than 70%, dust 6%, and clay 20% (Table 4). The substrate condition in the waters of the Wonogiri Regency is the type of substrate favoured by the lobster. Lobsters live in areas characterized by rocky sand beaches [34] and on coral
reeds [35]. The research area is the southern coast of Java which has characteristics of rocky and sandy beaches and is a distribution area of lobster in Indonesia.

Table 4. Substrate characteristics of lobster fishing areas in Wonogiri Regency waters.

| Location | % Sand  | % Dust  | % Clay  |
|----------|---------|---------|---------|
| P-1      | 72.66   | 8.18    | 19.15   |
| P-2      | 76.32   | 4.21    | 19.47   |
| P-3      | 73.30   | 7.43    | 19.26   |
| P-4      | 75.14   | 5.26    | 19.59   |
| P-5      | 73.59   | 5.77    | 20.64   |
| P-6      | 74.61   | 6.16    | 19.22   |

4. Conclusion
Lobster in Wonogiri Regency waters is dominated by double-spined rock lobster (*P. penicillatus*), which is 677 or 87.58% of 773 samples. The sex ratio of male and female lobster lobsters is slightly balanced at 1.35: 1. The value of the growth coefficient (K) of female lobsters is 0.37 years\(^{-1}\) higher than that of male lobsters which is only 0.32 years\(^{-1}\). The natural mortality of male and female lobsters of 0.55 and 0.63, respectively, is much smaller than the mortality due to fishing of 1.80 and 2.21. Achievement of the rate of exploitation (E) of double spined rock lobster in Wonogiri Regency waters has exceeded the optimal level (0.5) or has experienced overfishing. Based on these results it shows that in the management of lobster fisheries in the Wonogiri Regency needs to be done with several approaches, including reducing the number of catching efforts and prohibiting fishing lobsters in berry (with eggs) conditions to sustain the lobster population naturally.

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