Stock Analysis of *Metapenaeus affinis* (H.Milne Edwards, 1837) on the North Coast of Central Java, Indonesia

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Abstract. This research aims at studying the length of first capture (Lc), length of sexual mature (Lm), and the stock analysis of *Metapenaeus affinis* in the North coast of Central Java, Indonesia. The field research activities were conducted from May 2016 to April 2017 using survey method and direct observations on the catch area of fishing units. The results showed that total length of the first capture for the male shrimp is 76.4 mm and 63 mm for females. The total length of first sexual mature is 116 mm. Y'/R' result analysis on male shrimp shows 0.595 maximum exploitation rate (E<sub>max</sub>), the rate of exploitation at E<sub>0.1</sub> is 0.521 and the rate of exploitation at E<sub>0.5</sub> is 0.352. While the female shrimp obtained is E<sub>max</sub> = 0.637, E<sub>0.1</sub> = 0.562 and E<sub>0.50</sub> = 0.373. To increase the production and to preserve shrimp resources, it is ideal if Lc = Lm, i.e. at a total length of 116 mm. In conclusion, the increase in length of first captured will increase Y / R ' and B / R'.

Key word : Lc, Lm, stock analysis, M.affinis, North Coast of Central Java

1. Introduction

The habitat of *Metapenaeus affinis* starts from subtidal edge to a depth of 60 m, prefer mud and sand-based mud substrates, while young shrimp found in intertidal areas [1-2]. This species during pascalarva and juvenile stages live in the estuary, but spawn at the bottom of inshore and offshore [2].

The exploitation of *M. affinis* in the north coast waters of Central Java was done by trawls and seine nets, which have been banned by the Indonesian government based on Fisheries and Marine Ministerial Regulation No 2 KP / Permen-KP / 2015 about the prohibition of the use of trawls and seine nets in the fishery management territory of Indonesia's republic fisheries management, such as trawls, danish seine, etc.

Several studies have been conducted on *M. affinis*, such as their age and growth in Mumbai [3], abundance and seasonal migrations [4], biology, assessment, and management [5-6], population dynamics, and exploitation at Kuwait [7]. Previous research on *M. affinis* in the northern waters of Central Java mainly focuses on growth, mortality and exploitation rates [8]. The results show that mortality rates are high and have been over-exploited (E> 0.5). Therefore, further research is needed. This study aims to examine the optimum size that should be captured, the first size of mature sexual and the results per optimum recruit. Besides, for the exploitation of *M. affinis* shrimp can be sustainable and provide optimum benefits for fishermen.

2. Material and Methods

2.1. Sampling Method.

This study was conducted in the northern coastal waters of western Central Java, starting from the northern waters of Brebes Regency (in the west) to Kendal Regency (in the east). Sampling was taken 12 times (May 2016 until April 2017). Shrimp samples were obtained from catch result by using danish seine fishing gear, at 10 places of fish auction (TPI), i.e. Kaliwlingi and Kluwud (Brebes regency), Larangan
and Suradadi (Tegal regency), Asemdoyong and Tanjungsari (Pemalang regency), Jambean (Pekalongan regency), East Roban (Batang regency) and Bandengan and Tawang (Kendal regency). Shrimp samples were taken using systematic sampling method. The number of sample fishing vessel units is adjusted to the number of boats landing on a daily basis. If in one day the number of landed vessels catching the *penaeid* shrimp is less than 5 (five) vessels, then it will be taken one as a sample. In addition, if there are 5-10 vessels, and then 2 (two) vessels samples are taken. Moreover, the vessel no 1 (one) and no 6 (six) are taken and so on every 5 (five) vessels, as presented by Potier and Sabdotomo [9]. When the shrimp catch is less than 3 (three) kilograms, then all the catch is taken as a sample. Meanwhile, if the shrimp catch is between 3-10 kg, then only 3 kg of the catch is taken as a sample. Moreover, if the catch is above 10 kg, then the sample is taken as much as 20% of the whole catch. The method has been used in a previous study (8).

**Figure 1.** The sampling sites in the northern coastal waters of western Central Java, Indonesia

### 2.2. Data collection.

The recorded data included sex, carapace length (mm), total length (mm), body weight (gram), and gonad maturity level. Total length and the carapace length were measured using a caliper with 0.5 mm accuracy, from the tip of the carapace (eye base) to the back of the rear carapace. The weight of shrimp and gonad was measured using an electric scale, with 0.05-gram precision. The sex of the shrimp was identified by observing the ventral part of the shrimp (in pleopods and periopods). The maturity level of gonads was identified morphologically by observing the color, shape and size of the gonads, with the help of loops based on [1][10-11] and King [12].
2.3. **Data Analysis.**

Standard logistic curve method from Spearman-Karber [13] is used to determine the length first capture using danish seine tool (Lc). The method to find out the length first mature gonad by plotting the cumulative frequency percentage of gonad shrimp with the length of the carapace, then calculated using the standard logistic model as follows [14]:

\[
Y(\%) = \frac{100}{1 + ae^{-bx}}
\]  

(1)

Where: \(Y(\%)\) is the cumulative percentage, \(a\) is a constant, \(b\) is a slope, and \(X\) is the total length. Plotting \(Y\) and \(X\) will be obtained the logistic curve, where the cut point between the curve with 50% cumulative is the length when 50% of gonad ripe or also called the length of first matured (\(L_{m50}\)).

Stock analysis is counted by the result per recruit relative (\(Y'/R\)) and biomass per recruit relative (\(B'/R\)) from Beverton and Holt [15], as follows:

\[
\gamma = \frac{Y}{(RW_{c})} = E^n \sum_{n=0}^{\infty} \frac{Un(1 - c)n}{1 + (nK/M)(1 - E)}
\]  

(2)

Where \(\gamma\) = yield per new addition without unit, \(E =\) exploitation rate, \(M =\) natural mortality rate, \(c = \) ratio of \(L_c / L_\infty\), \(K, L_\infty\) and \(t_0\) is von Bertalanffy growth parameter, \(Y =\) result catch, \(R =\) abundance in age group \(L_c\), and \(Un =\) is the sumasi coefficient, taken value 1, -3, 3, -1 for \(n = 0, 1, 2, 3\).

To examine the effect of \(L_c\) change on results per new addition of reparameterization was made by Beverton and Holt (15) as follows:

\[
Y' = \frac{Y'}{R} = \frac{Y}{N(t_n)W_{\infty}} = (1 - c)^{M/K} \cdot \gamma
\]  

(3)

To facilitate the calculation, the equation can be written in another way to be:

\[
(Y / R)' = E * U^{M/K} * (1 - \frac{3U}{1 + m} + \frac{3U^2}{1 + 2m} + \frac{U^3}{1 + 3m})
\]  

(4)

The relative yield (\(Y'\)) is a function of the rate of exploitation (\(E\)), \(c=(L_c/L_\infty)\) and \(M/K\). The first two parameters, \(E\) and \(c\) can be controlled, while \(M/K\) is only the biological parameters needed in the analysis. This model can be used to determine the optimum combination of the number of fishing attempts (measured by fishing mortality rate, \(F\)) and size when first caught (\(L_c\)), which will result in maximum sustainable yield. The variables required in this analysis are \(L_{\infty}\) (mm), \(K\) (per year), \(Z\) (per year), \(M\) (per year), \(F\) (per year), \(E\), \(L_c\) (mm) and \(t_0\) (year). The variables are obtained from previous.

3. **Results**

3.1. The length of first captured (\(L_{c50}\)).

The total length of first caught using a danish seine (\(L_{c50}\)) is 76.4 mm for male and 63 mm for female, weighing 3.44 grams (male) and 1.8 grams (female) (Figure 2). On the total length of *M. affinis* shrimp, the shrimp is allegedly aged 102 days or 3.37 months (male), while the female is only 64 days or 2.13 months. Based on these data, it shows that female shrimp is more quickly caught, with smaller size and younger age.
3.2. The total length of the first sexual mature ($L_{m50}$).

The calculation result shows that the total length of first sexual mature *M. affinis* female is 116 mm (Figure 3).
3.3. Stock analysis based on the yield per recruit relative (Y/R').

The number of young *M. affinis* shrimp entering fishery on the northern coast of Central Java waters is not known, so the amount of new shrimp addition is assumed using relative yield, i.e. the yield per recruit relative (Y'/R) and biomass per recruit relative (B'/R). Y/R method can be used to determine an optimum combination between the capture effort and the size of first captured (Lc) that will result in maximum sustainable yield (MSY). The variables required in this analysis are presented in Table 1.

Table 1. Variables required for the calculation of (Y'/R) of *M. affinis*

| Parameter      | Average       |
|----------------|---------------|
|                | Male          | Female        |
| L∞ (mm)        | 168           | 178.5         |
| K (per year)   | 1.8           | 1.91          |
| Z (per year)   | 6.9           | 4.6           |
| M (per year)   | 1.23          | 1.6           |
| F (per year)   | 5.68          | 3.02          |
| E              | 0.82          | 0.62          |
| Lc (mm)        | 76.4          | 63            |
| t₀ (year)      | -0.053        | -0.049        |

The total length of the first capture (Lc) of *M. affinis* was 63 mm (female), the maximum exploitation rate (Eₘₐₓ) is 0.595, the exploitation rate at E₀.₁ is 0.521 and the rate of exploitation at E₀.₅ (exploitation rate which will result in a biomass reduction of 50% ) is 0.352. While male shrimp’s Lc = 76.4 mm, with Eₘₐₓ = 0.637, E₀.₁ = 0.562 and E₀.₅ = 0.373 (Figure 4).

![Figure 4](image_url)

Figure 4. The value of relative yield per recruitment (Y/R') and biomass per relative recruitment (B/R') as a function of exploitation rate of *M. affinis* (A = female, B = male)

If the size of the length of first caught (Lₐ₅₀) is increased in equal size to Lₐ₅₀ (the total length of the first mature = 116 mm), then Eₘₐₓ = 0.8, E₀.₁ = 0.73 and E₀.₅ = 0.41. While male shrimp with Lₐ₅₀ is increased to 111 mm, then it obtains Eₘₐₓ = 0.79, E₀.₁ = 0.71 and E₀.₅ = 0.41 (Figure 9). The increase in the average captured size will increase Y/R' and B/R'.

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**Note:** The image referenced in the text is not provided, and the URL is not valid. The text is interpreted based on the visible information and the context provided.
Figure 5. The Plots of yield per relative recruitment \((Y/R')\) and biomass per relative recruitment \((B/R')\) as the function of exploitation rate, with \(L_c\) value of female \(M.\text{ affinis}\), is 116 mm (A) and \(L_c\) of male \(M.\text{ affinis}\) is 111 mm (B).

4. Discussion

The total length first capture of female \(M.\text{ affinis}\) was 76.4 mm or at carapace length was 18.7 mm. While total length of male shrimp was 63 mm or at carapace length = 14.58 mm. Based on the length-weight relationship, it is known that at a total length of 74.6 mm and 63 mm, the shrimp weight is 3.26 grams (females) and 1.73 grams (male). So, the shrimp are very small. This indicates that the fishing gear used, i.e. danish seines, is not selective. The results showed that the first sexual matured \(M.\text{ affinis}\) at 116 cm (total length) or 30,19 mm (carapace length). Gerami et al., [16] in the Hormozgan Province shrimp fishing grounds obtained \(L_{m50}\) was 27,12 cm (carapace length), smaller than that obtained in the northern coast waters of Central Java.

Analysis result on the yield per recruit relative \((Y'/R')\) shows maximum exploitation rate \((E_{max})\) of female \(M.\text{ affinis}\) shrimp is 0.595, the exploitation rate of \(E_{0.1}\) is 0.521 and the exploitation rate at \(E_{0.5}\) is 0.352. While male shrimp’s \(E_{max}\) = 0.637; \(E_{0.1}\) = 0.562 and \(E_{0.5}\) = 0.373. Saputra [17] got \(E_{max}\) value on \(M.\text{ elegans}\) shrimp in Segara Anakan waters of Central Java, Indonesia as equal to 0.54, \(E_{0.1}\) = 0.47 and \(E_{0.5}\) are 0.33. Nurul Amin et al. [18] described on \(A.\text{ intermedius}\) shrimp in Malaysia obtained \(E_{max}\) = 0.65, \(E_{0.1}\) = 0.5 and \(E_{0.5}\) = 0.34. Saputra and Subiyanto [19] also reported on white shrimp \((P.\text{ merguiensis})\) in Segara Anakan lagoon Cilacap, Central Java which obtained \(E_{max}\) = 0.681, \(E_{0.1}\) = 0.552, and \(E_{0.5}\) = 0.357. While Wahhab [20] at Yemeni Red Sea waters on male \(P.\text{ semisulcatus}\) shrimp obtained greater \(E_{max}\) = 0.918; \(E_{0.1}\) = 0.804 and \(E_{0.5}\) = 0.391, female shrimp \(E_{max}\) = 0.855; \(E_{0.1}\) = 0.753, and \(E_{0.5}\) = 0.38. Compared to these studies, \(Y'/R\) of \(M.\text{ affinis}\) shrimp in the northern coastal waters of Central Java is similar to that of \(M.\text{ elegans}\) in the Segara Anakan lagoon of Central Java, but is smaller than \(P.\text{ merguiensis}\) in the same waters and \(P.\text{ semisulcatus}\) in the waters of the Red Sea, Yemen as well as \(A.\text{ intermedius}\) at Coastal Waters of Malacca, Malaysian Peninsula. Therefore, it is necessary to hold exploitation management in order to ensure the sustainability of resources and to maximize the production of \(M.\text{ affinis}\) shrimp. Management is conducted by setting the size of the captured shrimp. The size of the shrimp which should be captured at \(L_c = 116\) mm, with 12 grams individual weight. This length is equal to the size of first gonad mature \((L_{m50\%})\). In short, 50% of female shrimp at the length has ever spawned. If it can be conducted \(M.\text{ affinis}\) shrimp consequently may have a chance to breed. In addition, the catch result will increase, as \(Y'/R\) increases to \(E_{max} = 0.705, E_{0.1} = 0.411, E_{0.5} = 0.774\).
Setting the mesh size to capture shrimp with certain size and length is generally less effective, because shrimp have many limbs. Therefore, the arrangement to obtain the size of shrimp at a given length is excellent if it is done by prohibiting non-selective fishing gears (such as trawl, danish seine and so on), and replacing them with a selective catching tool (such as trammel net). The banning of drag-pull fishing gear and replacing it with selective fishing tools such as trammel net to catch shrimp will considerably reduce the exploitation rate, increase efficient use of shrimp resources, and increase the fishermen’s production and income.

In their previous study, obtained the length-weight relationship for *M. affinis* as $W = 0.000007TL^{3.02}$. Based on those equation then the total length of shrimp of 74.6 mm have weight of 3.26 grams [8]. Therefore one kilogram contains 307 individuals, and the price is IDR15,000/ kg. Saputra *et al* [8] also obtained the equation of length and age relationship as $L_t = 178.5(1-e^{-1.91(t + 0.049367)})$. Based on those equation, the total length of 74.6 mm shrimp is predicted to be 0.295 years old or 3.6 months. Based on the same equation, the total length of shrimp is 116 mm, weight was 12 grams (1 kg contains 83 individuals) of 0.62 years old (7.5 months).

Based on the previous research [8], the equation $N_t = N (t + dt) \times \exp (-Z \times (t + (t + dt)))$, then 307 individuals of shrimp 0.294 years old will be 182 individuals at the age of 0.62 years (assuming $Z = M$, due to no catch), weighing 12 grams/indv., meaning shrimp production to 2.18 kg (182 * 12 grams). The shrimp price at that size is IDR 50,000/kg, so the fishermen's receipts to IDR 109,000 indicate that the initial fishermen income of only IDR 15,000 will increase to IDR. 109,000, - (increase 626%) in 4 months later.

5. Conclusion

Based on the result of this research, it can be concluded that total length of the first captured of male *M. affinis* is 63 mm with weight of 1.7 grams at age of 0.265 years old or 3.2 months, while the total length of female shrimps 74.6 mm with weight of 3.26 grams at age of 0.295 years old or 3.6 months. The total length of the first mature of female shrimp is 116 mm with weight of 12 grams at 0.62 years old or 7.5 months. Based on the values of $L_0$, $Y/R'$ and $B/R'$, the status of *M. affinis* shrimp fishery in the northern coastal waters of Central Java is categorized as overfishing or growth overfishing.

To get sustainable yield of *M. affinis* as well as to get profitable business, the total length of the first captured must not be less than 116 mm with 12 grams weight.

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