Growth, Mortality, and Exploitation Rate of *Penaeus merguensis* in the North Coast of Central Java, Indonesia

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Abstract

One of the most-caught shrimp in north coast of Central Java is *Penaeus merguiensis. However, little is known on the population biology of the organisms. This study was aimed to investigate length-weight relationship, growth, length at first capture (L_{c50}), mortality rate, and exploitation rate of P. merguiensis in Western part of Central Java's northern coastal waters. The study was conducted from May 2016 to July 2017 using survey method. Samples were taken for 15 times (month) from 9 coastal fishing ports. The result shows that the relationship of the carapace length and weight is negative allometry. The growth parameters of CL_∞ and K were 52.5mm and 1.3 y^{-1} (male) and 57.25mm and 1.2 y^{-1} (female). Total mortality rate (Z), natural mortality rate (M), and fishing mortality rate (F) were 4.51 y^{-1}, 1.86 y^{-1} and 2.65 y^{-1} (male), and 5.36 y^{-1}, 1.72 y^{-1}, and 3.64 y^{-1} (female), respectively. The exploitation rate (E) of male banana shrimp was 0.59, and for female shrimp was 0.68. The result shows that the exploitation level has exceeded the optimum level (E>0.5). Recruitment of P. merguiensis may occur the whole year, but it peaks were in March and August (male), April and August (female). Carapace length of first captured (CL_{c50}) was 20.63mm (male) and 18.28mm (female). It means that the sized of captured P. merguiensis is less than the size of first mature (CL_{m50}) or growth overfishing and as a result, disrupting the availability of adult shrimp. The condition occurs due to the size of cod-end mesh measured 0.75inc.*

Keyword*s: natural population, exploitation, white shrimp, banana shrimp*

Introduction

North coastal waters of Central Java are a part of Java Sea and included in Indonesia Fisheries Management Area (FMA) 712. The waters are potential for shrimp resources and therefore, a high-exploited fisheries area. National Stock Assessment Commission published a study that, in 2016, the utilization level of Penaeid shrimp in this area has reached 121% of its sustainable potential. *Penaeus merguiensis* or white shrimp of banana shrimp is the most-caught valuable species in western part of northern coastal waters of Central Java.

Research on the length-weight relationship, growth, mortality rate, and exploitation rate is important as the basis of shrimp management. Several studies conducted on *P. merguiensis* related to the research topic are among others Tirtadanu and Ernawati (2016); Kembaren and Suman (2013); Nurdin and Kembaren (2015); Saputra and Subiyanto (2007); Siregar *et al.* (2014); Mane and Deshmukh (2011).

P. merguiensis spawn at the bottom of the water, between inshore and offshore. The shrimp is hatched as *nauplii* and growing as *zoea*, which is planktonic and carried away by current to the waters around the beach or estuary. It arrives in coastal waters in post larvae phase then grows into the juvenile and young shrimp. The shrimp will migrate to the sea to become adult shrimp and spawn (Bauer, 2011; Sheaveset *et al.* 2012). Shrimp caught in estuaries and coastal waters are the main issue of fisheries in many areas because the target of shrimp catch is post-larva, juvenile, and young shrimp. The gears used to catch were mini trawl, danish seine*, arad, dogol*, and *sodo*, which has a low level of selectivity. Although the gears have been prohibited based on the Regulation of Ministry of Marine Affairs and Fisheries No. 2/2015 and No. 71/2016, yet the regulations have not effectively implemented. This study was aimed to analyze length-weight relationship, growth, mortality rate, and exploitation rate of *P. merguiensis*.

Materials and Methods

Samplings were carried out for 15 (fifteen) times (months), from May 2016 to July 2017 in northern coastal waters of Brebes to Kendal regency
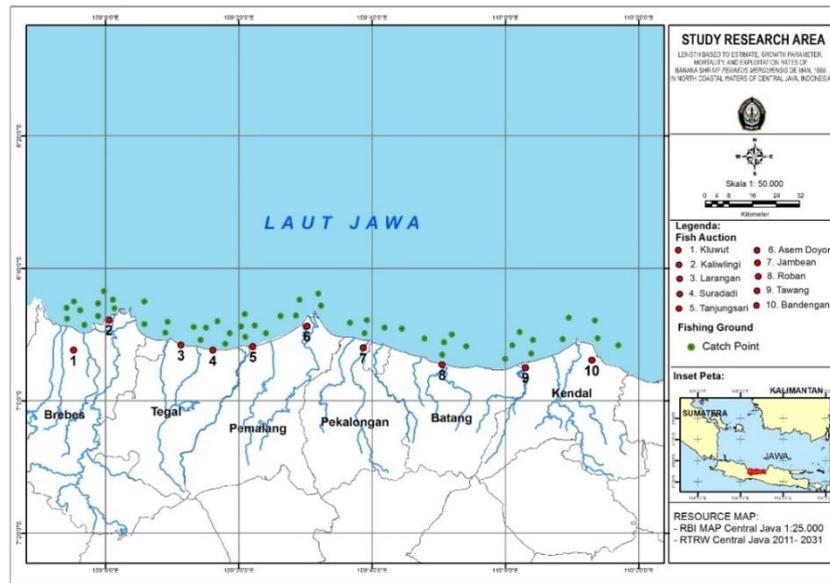
Figure 1. Research Map in the northern coastal waters of western Central Java, Indonesia

based on Saputra (2018). See Figure 1. Sample of shrimps were taken from the catch using Danish seine, in following fish landing bases (Coastal Fishing Port/CFP) *i.e.* Kaliwlingi and Kluwud (Brebes regency); Larangan and Suradadi (Tegal regency); Asemdoyong and Tanjungsari (Pemalang regency); East Roban (Batang regency); Bandengan and Tawang (Kendal regency). Systematic sampling method was used to determine the sample fishing vessels. The number of sample fishing vessel units was adjusted to the number of boats landing on a daily basis.

Data measurement

Data measurement and data recording were based on Saputra (2018), including sex, carapace length (mm), total length (mm), body weight (g), and maturity level of the gonad of the shrimps. Total length and carapace length were measured by using a caliper with 0.1mm accuracy, from the tip of the carapace (eye base) to the back of the rear carapace. Shrimp weight was measured using an electric scale, with 0.05g precision. Shrimp sex was identified by observing the ventral part of the shrimp (in pleopod and periopod). Shrimps maturity level of gonads was identified morphologically by observing the color, shape, and size of the gonads, with the help of loops based on Motoh (1981), Croccos and Kerr (1983).

Data analysis

Length-weight relationships were determined according to Sparre and Venema (1999). The linear

equation is Log W=Log a + b Log CL. The growth parameters L_∞, and K were estimated using Elefan software that is available in Fisat II program. The age at which the organism has mean length zero (t_0) was estimated by Pauly's formula, that is Log ($-t_0$) =-0.392-0.275 log L_∞ -1.038 log K. The total mortality (Z) was estimated by means of the catch curve based on catch converted into length (Pauly, 1984). Natural mortality rate (M) was estimated based on Pauly's empirical equation, that is Log M=-0.0066 - 0.279 Log L_∞ + 0.6543.Log K + 0.4634 Log T. Recruitment pattern was analyzed using FiSAT II.

Result and Discussion

Structure of shrimp size

The size structure of male *P. merguiensis* shrimp during 15-month sampling is presented in Figure 2. The catch was typically dominated by one cohort. In May 2016, the carapace length was 22.5mm, then replaced by shrimp having the length at 25mm in June, and changed to 27.5mm in July. In August, the module returned to carapace length 22.5mm, then grew to 25mm in the following month. In November, the size of carapace was 20mm, then grew to 22.5mm in the following month.

Based on the data, it can be concluded that the recruit of *P. merguiensis* was 20-22.5mm. Based on its weight, the catch was dominated by 3-gram shrimp (estimated weight: 2-4g) as much as 41.3%, and followed by 5g shrimp as much as 25.5% (Figure 3.). The result shows that the size of caught shrimp was too small.
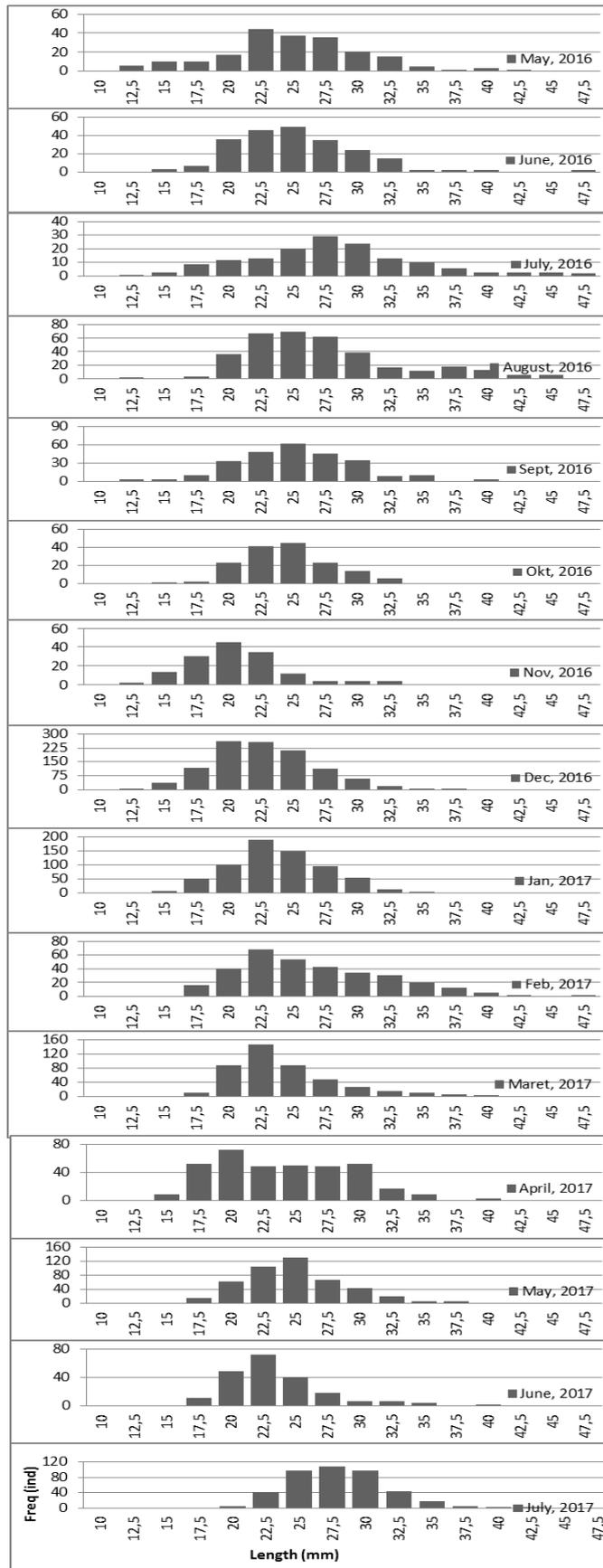
Figure 2. Size structure of *P. merguiensis* during the study (base on length)

Carapace length of the first-caught (CL_C50)

Carapace length of the first-caught of male *P. merguiensis* was 20.63mm, while female shrimp was 18.23mm (Figure 4.). The gears used to catch *P. merguiensis* shrimp were minitrawl/*arad*, *dogol*, and *sodo*. The mesh size of net comprised 0.75inch.

Carapace length-weight relationship and condition factors

The calculation on the length-weight relationship of *P. merguiensis* shows that male shrimp and female shrimp are negative allometry (b<3). The equations of the shrimp length and weight during research are (Figure 4.):
Male shrimp: $W=0.004 \times CL^{2.32}$;

Female shrimp: $W=0.0027 \times CL^{2.44}$.
Condition factor of male shrimp was 1.1 while female shrimp was 1.3. It means that female shrimp has bigger size than male shrimp.

Growth parameters

The growth of female *P. merguiensis* was faster compared to male shrimp. It can be seen from the value of K (index of growth curve) of female shrimp (1.2) having $CL_\infty=57.25$mm was bigger than male shrimp having K=1.3 and $CL_\infty=52.5$mm. The growth of male *P. merguiensis* was based on the equation $CL_t=52.5 (1-e^{-0.41(t+0.103072)})$, while female *P. merguiensis* was based on $CL_t= 57.25 (1-e^{-0.69(t+0.109102)})$. Von Bertalanffy growth curve for *P. merguiensis* is presented in Figure 5.
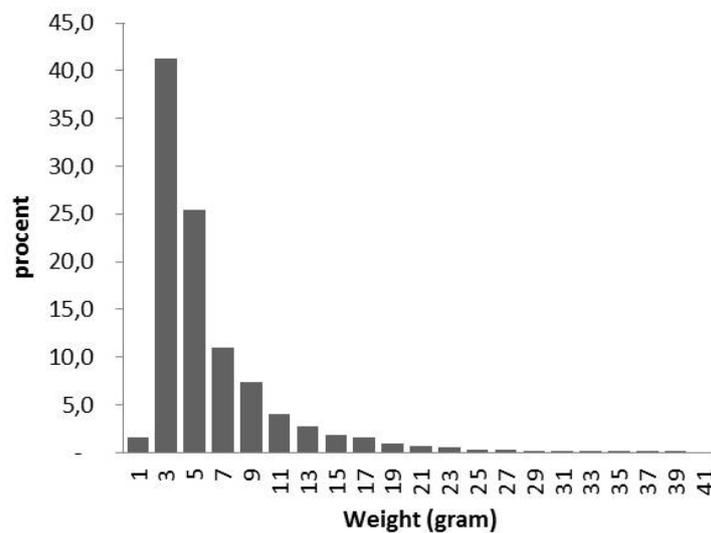

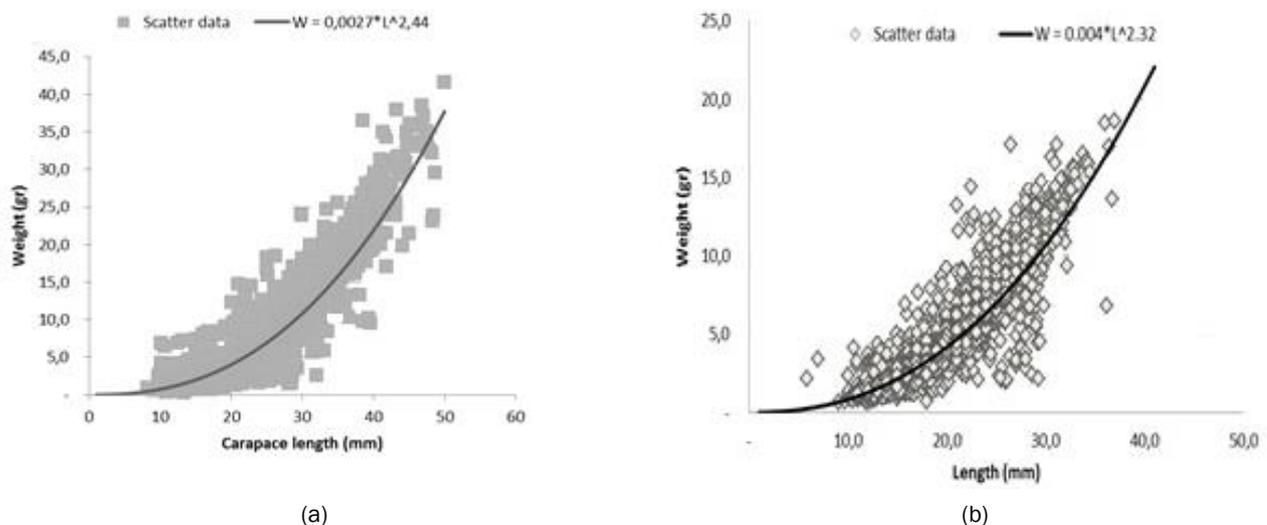**Figure 3.** Size structure of *P. merguiensis* during the study (based on weight)

(a)

(b)

Figure 4. Length-weight relationship of shrimp *P. merguiensis* female (A) and male (B) the northern coastal waters of Western Central Java

Recruitment pattern

The recruitment occurs the whole year, and recruitment peak is in April and August for female shrimps, and in March and August for male shrimp. Figure 6. The size of carapace length during recruitment is 20-20.5mm.

Mortality and exploitation rate

Total mortality rate (Z) represents fishing mortality (F) and natural mortality (M). For male *P merguiensis*, the value of Z was 4.51 y^{-1}, M=1.86 y^{-1}, and F=2.65 y^{-1} (Figure 8.). The exploitation rate (E=F/Z) was 0.59. While for female *P merguiensis*, the value of Z=5.36 y^{-1}; M=1.72 y^{-1}, F=3.64 y^{-1} and E= 0.68. It means that the exploitation of female *P. merguiensis* has exceeded the optimum level or overfishing. The facts also suggest that female shrimp has exploited more than male shrimp.

Length-weight relationship of *P. merguiensis* in the Western of the northern coastal water of Central Java is negative allometry, for both male and female shrimp. Female shrimp has bigger size compared to male shrimp, based on female shrimp condition factor 1.3, fatter or more plump than male shrimp (Condition Factor=1.1). Tirtadanu and Ernawati (2016) in northern coastal water of Pemalang Regency, Central Java also obtained negative allometry pattern for both male and female shrimp. Suryanti *et al*. (2018) obtained negative allometry for male shrimp and positive allometry for the female pattern when conducting length-weight relationship of *P. merguiensis* in mangrove ecosystem, North Sumatera.
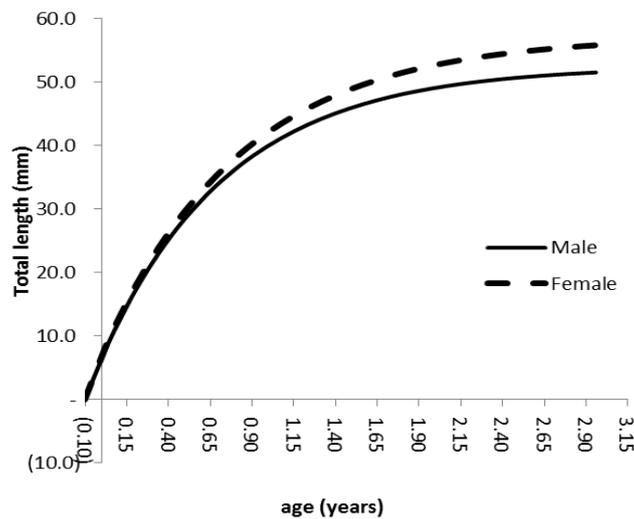

Figure 5. Shrimp growth curve of *P. merguiensis* shrimp in the northern coastal waters of Western Central Java
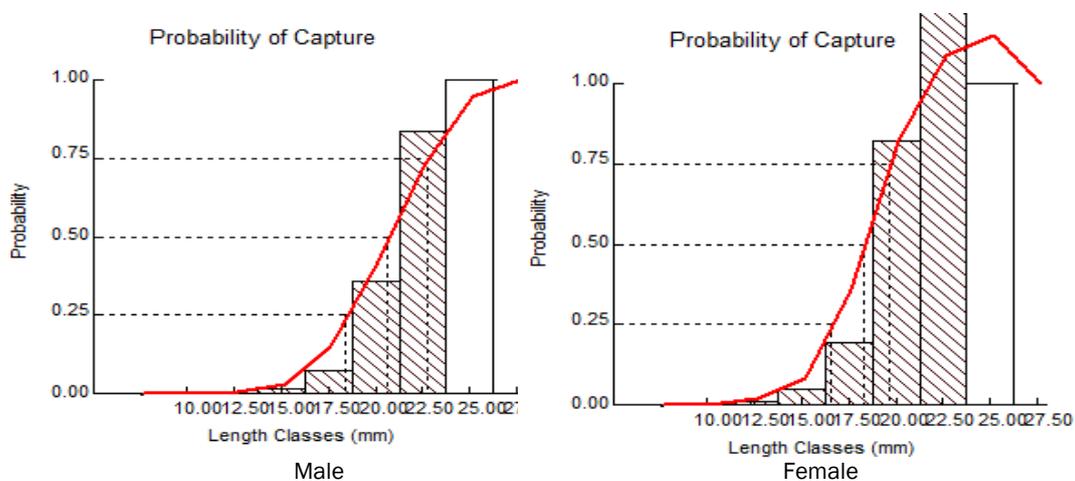

Figure 6. The carapace length curve was first caught *P. merguiensis* shrimp female and male
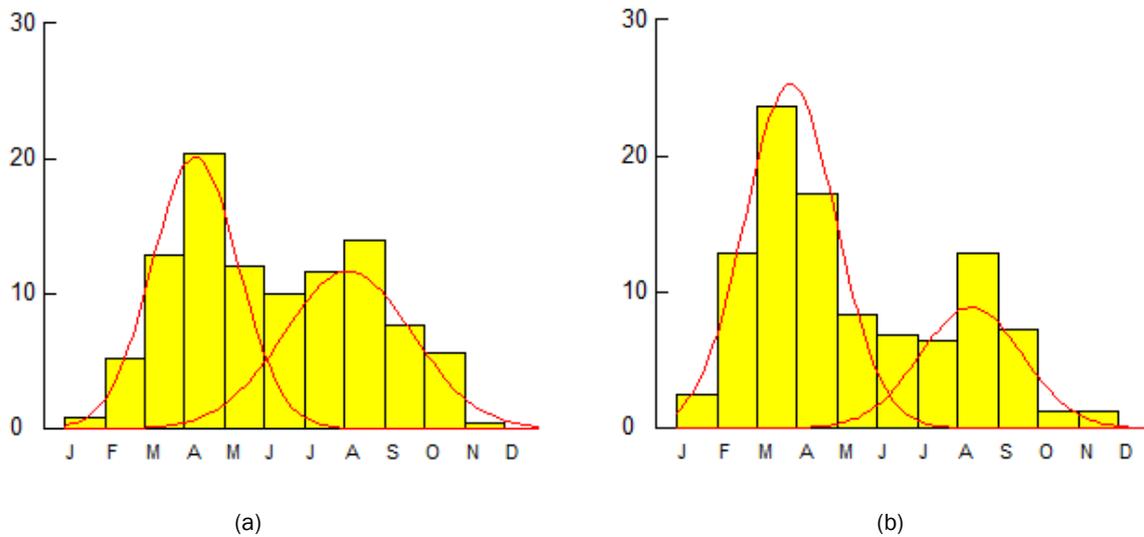
Figure 7. Pattern recruitment of *P. merguiensis* shrimp on the western part of the northern coastal waters of Western Central Java (females:A and males:B)
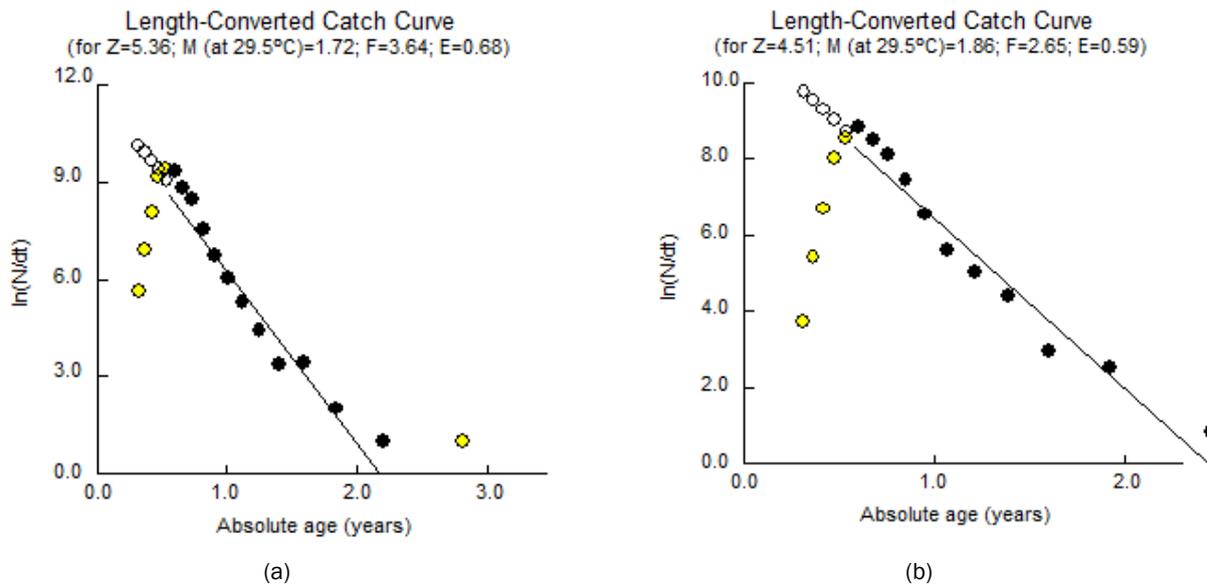

Figure 8. Curve of mortality rate of Female (A) and female (B) *P.merguiensis* shrimp in the northern waters of western Central Java.

The size of shrimp during recruit using Minitrawler, Danish seine, and sodo was 20-22.5mm, weighing 2-4g. The first-catch carapace length of male *P. merguiensis* was 20.9mm, while for female 19.6mm. Saputra (2007) in Segara Anakan Laguna, Cilacap using *Apong* obtained value of $CL_{c50\%}$=18mm. Kembaren and Suman (2013) in Tarakan waters, East Kalimantan using minitrawls obtained $CL_{c50\%}$= 35mm and L_{m50}= 33.86mm. Tirtadanu and Ernawati (2016) in Pemalang Regency waters using trammel net and arad obtained $CL_{c50\%}$ = 29.4mm and L_{m50}= 42,85mm. Nurdin and Kembaren (2015) in Sampit waters, Central Kalimantan using trammel net gear and Danish seine obtained $CL_{c50\%}$= 30.05mm and L_{m50}= 39.4mm. Based on the data presented, it is obvious that the size of caught shrimp using *arad, sodo*, and Danish seine was relatively small (19.9mm and 20.9mm) and far below L_{M50}. The condition is a serious threat to the sustainability of *P. merguiensis* in the coastal waters because of the availability of shrimp broodstock.

Von Bertalanffy growth parameter of *P. merguiensis* obtained were CL_{∞}= 57.25mm, K= 1.2 y^{-1} (female) and CL_{∞}= 52.5mm, K= 1.3 y^{-1} (male). Nurdin and Kembaren (2015) in Sampit, Central Kalimantan using trammel net and Danish seine

obtained found the value of CL_∞= 57.8mm and K=1.45 y^{-1}. Safaie (2015) in northern coastal waters of Persian Gulf, Iran, obtained the value of CL_∞= 48mm, K= 1.6 y^{-1} for male and CL_∞= 54mm, K= 1.8 y^{-1} for female. Momeni *et al*. (2016) researched Strait of Hormoz, the Persian Gulf using bottom trawl and obtained the value of CL_∞= 39.5mm, K= 1.8 (male) and CL_∞= 50mm, K= 1.5 y^{-1} (female). Kembaren and Suman (2013), based on mini trawl catch in Tarakan waters, North Kalimantan, obtained CL_∞ *P.merguiensis* 80mm, with K= 1.45 y^{-1}. Bhadra and Biradar (2000) in their length-based study in Mumbai coastal waters obtained L_∞= 220mm, with K= 1.8 y^{-1} (male) and CL_∞= 281mm with K= 1.7 y^{-1} (female). Mane and Deshmukh (2011) in their study in Maharashtra India obtained L_∞= 203.7mm with K= 2.15 y^{-1} (male) and L_∞= 254.9mm with K= 1.9 y^{-1} (female).

The value of L_∞ depends on gear selectivity and fishing ground. The operational area of Minitrawl*,* Danish seine, and *sodo* is coastal water, thus having a small value of L_∞. Trawl, with its low selectivity and operated offshore, has bigger L_∞ value. Next, trammel net is more selective and operated offshore. Thus the value of L_∞ is bigger

The value of K is curve parameter showing the speed of fish in obtaining its maximum value (L_∞). The bigger K value shows a faster growth of shrimp. It indicates that the growth of *P. merguiensis* in northern coastal water of Central Java is slower compared to others based on the result of various studies.

Based on analysis on recruitment pattern, *P. merguiensis* has double recruitment pattern, and the peak occurs in April and August (female), and March and August (male). In Tarakan coastal waters, the peak of *P. merguiensis* recruitment occurs in May (Kembaren and Suman, 2013). Momeni *et al*. (2016) reported that *P. merguiensis* in Strait of Hormoz, Persian Gulf, has whole year recruitment pattern and peaks from July to November.

Estimated total mortality rate (Z), natural mortality rate (M), fishing mortality rate (F) and exploitation rate (E) of male *Penaeus merguiensis* in the western part of northern coastal waters of Central Java were Z=4.51 y^{-1}; M=1.86 y^{-1}, F=2.65 y^{-1} and E(F/Z)= 0.59. While the estimated rate for female shrimp was Z= 5.36 y^{-1}, M= 1.72 y^{-1}, F= 3.64 y^{-1}, and E= 0.68. Compared to other studies, the mortality rate is relatively lower. The mortality rate of *P. merguiensis* in Segara Anakan waters, Cilacap, Central Java, were bigger and recorded as Z= 7.02 y^{-1}, M= 1,96 y^{-1}, F= 5.06 y^{-1} and E= 0.72 (Saputra and Subiyanto, 2007). Kembaren and Suman (2013) in the research in Tarakan waters, East Kalimantan, obtained not different value Z= 4.85 y^{-1}, M= 1.76 y^{-1},

F= 3.09 y^{-1}, and E= 0.64. Nurdin and Kembaren (2015) in Sampit waters, Central Kalimantan, also obtained not different Z, recorded as 5.7 y^{-1}, M= 1.93 y^{-1}, F= 3.77 y^{-1}, and E=0.66. Syafaei (2015) for his research in the Persian Gulf obtained Z= 8.27 y^{-1}, M= 2.1 y^{-1}, F= 6.17 y^{-1}, and E= 0.87 for male shrimp and Z= 6.97 y^{-1}, M= 2.19 y^{-1}, F= 4.78 y^{-1} and E= 0.69 for female shrimp. Bhadra and Biradar (2000) in Mumbai coastal waters obtained the values of Z=9.79 y^{-1}, M= 2.8 y^{-1}, F=6.99 y^{-1} and E= 0.7(male). While for female shrimp, the value of Z=7.44 y^{-1}, M=2.6 y^{-1}, F=4.84 y^{-1} and E=0.65 (female). Momeni *et al*. (2016) in Strait of Hormuz, Persian Gulf obtained the values of Z=5.9 y^{-1}, M=2.9 y^{-1}, F=3.0 y^{-1} and E=0.51 (male) and Z=5.7y^{-1}, M=2.5 y^{-1}, F=3.2 y^{-1} and E=0.56 (female). The total mortality rate of *P. merguiensis* in the western of northern coastal waters of Central Java is relatively lower than other waters. The natural mortality rate is similar to the other waters in Indonesia, yet lower than Iranian water. The most influencing factor towards M is the temperature of waters. Based on the explanation, it is obvious that the level of total mortality rate is influenced by the level of Fishing Mortality (F). Thus, the exploitation rate (E) of *P. merguiensis* has exceeded the optimum level (0.50).

Conclusion

The length-weight relationship of *P. merguiensis* is a negative allometric. The growth rate of *P. merguiensis* in the northern coast waters of Central Java was found relatively low, the value of K ranges from 1.2 to 1.3 y^{-1}. The total mortality rate (Z) of shrimp *P. merguiensis* was quite high, Z ranges from 4.51-5.36 y^{-1}. The rate of exploitation (E) of shrimp *P. merguiensis* has exceeded the optimum limit, E ranges from 0.54 to 0.63 or has been over-exploited.

Acknowledgment

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