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Growth parameter, mortality, recruitment pattern, and exploitation rate of white shrimp *Penaeus indicus* in northern coastal waters of Western Central Java, Indonesia

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Abstract. *Saputra SW, Solichin A, Taufani WT, Rudiyanti S, Widyorini N. 2019. Growth parameter, mortality, recruitment pattern, and exploitation rate of white shrimp* Penaeus indicus *on the northern coast of Central Java, Indonesia. Biodiversitas 20: 1318-1324.* The aims of this study were to know the growth parameters, first lenght captured (Lc), mortality, recruitment pattern, and the exploitation rate of white shrimp (*Penaeus indicus* H.Milne Edwards, 1837) in the Western Coastal North Central Java Sea, Indonesia. Samples were collected from May 2016 to July 2017 using survey method and direct observations on fishing unit areas. The results showed that the relationship of the carapace length and weight is allometric. Based on the estimates of von Bertalanffy growth equation to the carapace length, the growth parameters of CL_∞ and K values in male were 37 mm and 0.97, while in female were 38.5 mm and 0.85. While, the rates of total mortality (Z), natural mortality (M), and fishing mortality (F) were 3.5, 1.67, and 1.84 for males, and 5.03, 1.51, and 3.52 for females, respectively. The exploitation rate (E) of male shrimp was 0.52 and of female was 0.7 indicating that female shrimp get higher capture pressure than the males. It also showed that the rate of exploitation has to exceed the optimum sustainable yield (E>0.5). Time recruitment occurred throughout the year, with two peak seasons, i.e., in April-June and September-November. Moreover, the length of the carapace during recruitment was 15-20 mm. While the carapace length of the first caught ($CL_{\infty 50}$) was 18.3 mm for male and 17.6 mm for female indicating that the *P. indicus* caught was still in the small size, as well as below the first mature gonad (CLm50 = 22-39 mm). This is because the mesh size of cod-end is 0.75 inches or about 2 cm.

Keywords: Growth parameter, mortality rate, North Coast of Central Java, recruitment pattern, white shrimp

INTRODUCTION

Penaeus indicus H. Milne Edwards in northern coastal waters of Western Central Java Province, Indonesia is the second most important economic species after *Penaeus merguiensis*. The price of *P. indicus* shrimp size 40, in the trader level, is 100,000 IDR per kilogram. *P. indicus* is one of the export commodities with high prices, and the second dominant catch after *P. merguiensis*. Both species are known as white shrimp and are almost always captured together at all stations. Exploitation of *P.indicus* shrimp using non-selective and environmentally friendly fishing gear, such as "arad"/mini trawl, has threatened the sustainability of this shrimp species. This is because the shrimp caught are young and immature shrimp, so they can break the life cycle. The fishing gear also damages the bottom of the waters, as a place to spawn various species of shrimp. This study was to determine the parameters of growth, mortality, recruitment patterns and the level of exploitation of *P. indicus* shrimp.

Penaeus indicus is found in the Western Indo-Pacific waters, i.e.: Eastern and South-eastern Africa to Southern China, Papua New Guinea and Northern Australia (FAO, 1980) at a depth of 2 to 90 m, on the base of mud or sand waters. *P. indicus* is, therefore, most abundantly exists in shallow waters with less than 30 m depth (FAO 1985). *P. indicus* is euryhaline and lives in brackish, estuarine and marine environments with temperature ranges between 18 and 34.5°C and salinity of 5 to 50 PSU (Kutty et al. 1971; Branford 1981; Khan et al. 2001; Macia 2004).

Shrimp capture in estuary and coastal waters is a major problem in many areas of the world (FAO 2000) and was strongly associated with growth overfishing which causes reduction and depletion of spawners (Garcia 1985; Courtney and Die 1995; FAO 1986, 1990, 2000; Abdallah 2004; Chando 2005; Saputra 2005a, 2005b, 2007, 2008). This phenomenon greatly affects recruitment in coastal waters as well as the stock recovery in marine waters. In the Western Coastal North Central Java Sea, shrimp capture has been using a variety of fishing gear, both seine net, and trawl, as derivatives and modification of trawl nets which have been banned since 1980 in the waters of western Indonesia. This study aimed to assess the size structure, recruitment patterns, growth parameters, mortality rate and stock analysis of *P. indicus.*

MATERIALS AND METHODS

Study area

This study was done in northern coastal waters (*Pantura*) of Western Central Java Province, Indonesia, from Brebes District (in the west) to Kendal District (in the east) (Figure 1). Purposive random sampling was applied in this study (Saputra 2018). Samples were collected 15 (fifteen) times, from May 2016 to July 2017. Those were included 7407 (1756 males and 5651 females) samples of shrimp, they were collected by *arad* and *sodo* with mesh in the cod end was about 0.75 inches at 10 places of fish landing base, i.e. Kaliwlingi (160 males and 782 females) and Kluwut (263 males and 1383 females) (Brebes District); Larangan (175 males and 299 females) and Suradadi (105 males and 345 females) (Tegal District); Asemdoyong (124 males and 264 females) and Tanjungsari (117 males and 151 females) (Pemalang District); Jambean (336 males and 938 females) (Pekalongan District), East Roban (156 males and 129 females) (Batang District); Bandengan (195 males and 1148 females) and Tawang (125 males and 212 females) (Kendal District). The systematic sampling method was used to determine the sample fishing vessels by daily basis.

Method of data measurement

The primary data collected were: sex, total length (mm), carapace length (mm), weight (gram), and gonad maturity level. Total length and carapace length were measured by calipers in 0.1 mm accuracy. Body weight was measured by an electric scale in 0.05-gram precision. Shrimp sex was seen from ventral part of the shrimp (in pleopods and periopods). The gonads maturity level is seen based on morphological observations of colors, shapes, and sizes (Motoh 1981, Croccos and Kerr 1983; King 1995).

Data analysis

The length-weight relationships were determined based on the equation of Sparre and Venema (1992), where $W = a * CL^b$ (W: weight; a and b: regression constants; CL: carapace length). The linear equation is Log W = Log a + b Log CL.

The parameters of the von Bertalanffy growth formula (VBGF), asymptotic length (L_∞) and index of growth curve (K) were analyzed using ELEFAN program which was provided in FiSAT II program package (Pauly and David, 1981). The theoretical age at zero length size (t_o) was obtained by Pauly's equation (Pauly 1980): Log ($-t_0$) =-0.392-0.275 log L_∞-1.038 log K. The total mortality rate (Z) was assumed by capture curve method which was converted to length (Pauly, 1984). Natural mortality rate (M) is assumed by Pauly's empirical equation (1980): Log M =-0.0066-0.279 Log L_∞ + 0.6543. Log K + 0.4634 Log T. The recruitment pattern was analyzed by using FiSAT II.

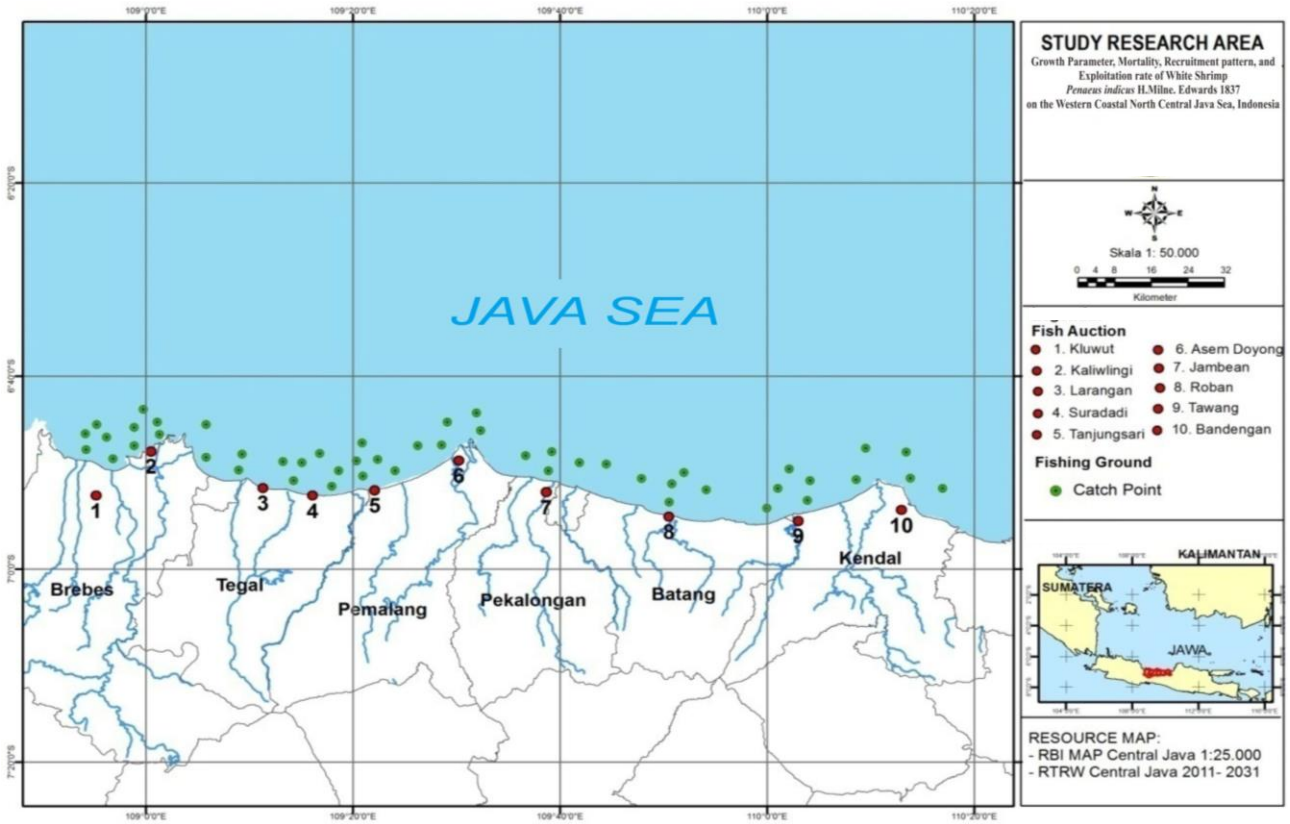

Figure 1. Research map offshore of northern coastal waters of Western Central Java, Indonesia. (resource MAP: RTRW Central Java, 2011-2031)

RESULTS AND DISCUSSION

Size structure

The size structure of male *P. indicus* during 15 months sampling was presented in Figure 2. The size composition of both male and female shrimps, of each sampling generally consists of one cohort (size group) with changing mode. In May 2016, the mode of the carapace was 20 mm.

Then it was replaced by a shrimp with 5.0-17.5 mm carapace length in June 2016. The pattern tends to repeat between 2-3 months. Recruitment occurs with mode of 15 mm carapace length, and the mode of the carapace length mostly captured mostly was at 17.5 and 20.0 mm.

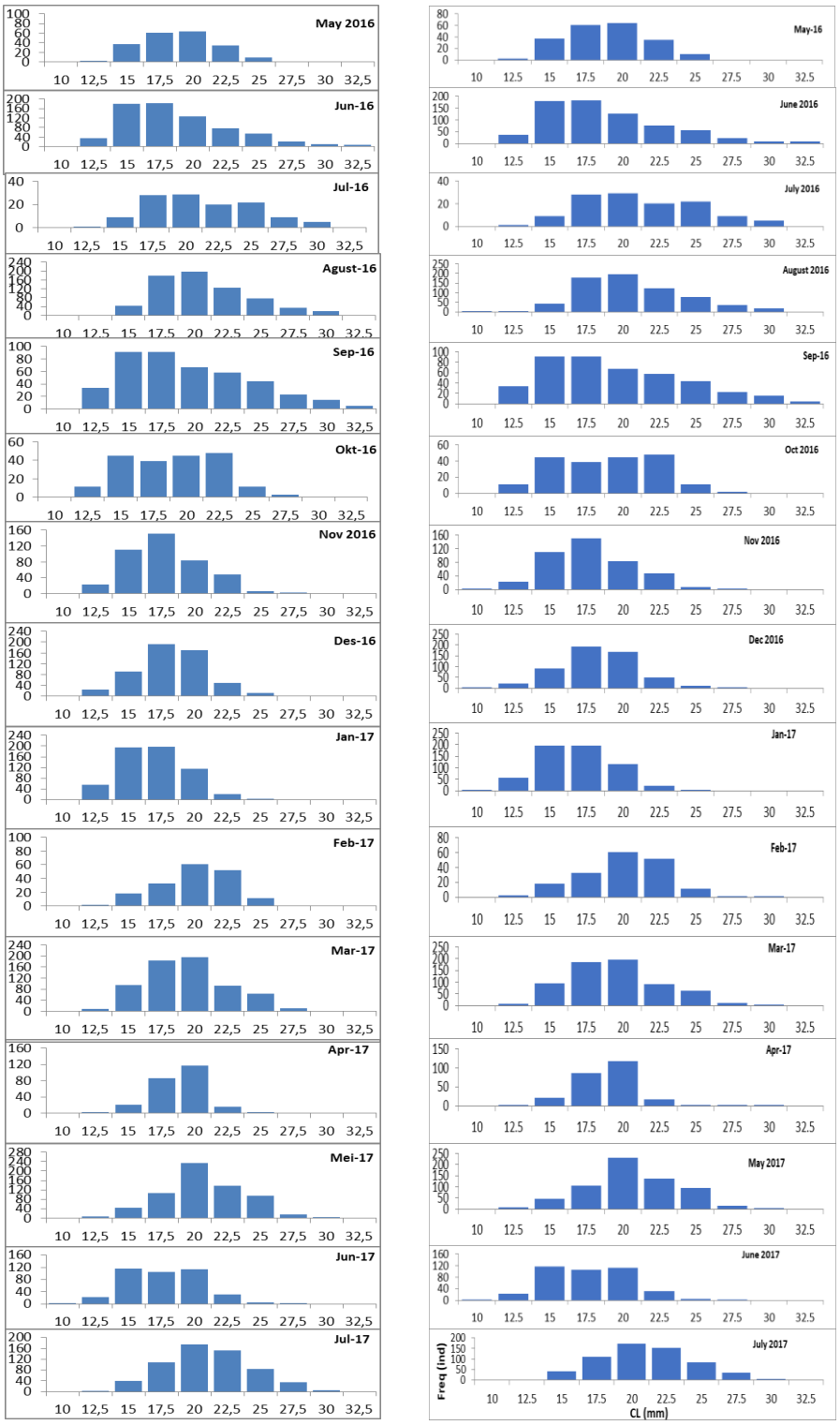

Figure 2. Size structure of *P.indicus* during the study (males, *righ* and females, *left*)

Length-weight relationship and condition factors of the carapace

Penaeus indicus length-weight relationship indicated that male and female shrimp were negative allometric (b <3). The length-weight equation of *P. indicus* during the study was:

Male shrimp : $W = 0.003 \times CL^{2.48}$;

Female shrimp : $W = 0.006 \times CL^{2.22}$.

The condition factor of male shrimp is 1.10, while the female shrimp was 1.09. The value of the condition factor shows that the plumpness level of male and female shrimps was not different.

The size of first captured of *P. indicus* shrimp (CL_{C50})

The first captured (Figure 4) indicates that males *P.indicus* were larger (18.3 mm) than the females (17.6 mm) (Figure 4). *P. indicus* was captured in coastal waters, with *arad*, *dogol*, and *sodo* fishing gear. Therefore, the captured shrimps mostly were small sized.

Growth parameters

The growth of female *P. indicus* is faster than the male one. This can be proven from the K value (growth curve index) of female shrimp (0.85) with CL_∞ = 38.5 mm, smaller than male shrimp, with K = 0.97 and CL_∞ = 37 mm. The bigger the K value is, the longer time required to capture CL_∞. The growth of male *P. indicus* shrimp was calculated using CLt equation = $37\ (1\text{-}e^{-0.97\ (t+0.0154)})$, while the female shrimp was used CLt equation = $38.5\ (1\text{-}e^{-0.85\ (t+0.103)})$. Von Bertalanffy growth curve of *P. indicus* is presented in Figure 5.

Recruitment pattern of *P. indicus* shrimp

The result of recruitment pattern analysis of both *P. indicus* sexes is presented in Figure 6. Recruitment time occurs throughout the year, with peak recruitment in April-June and September-November for male, while female recruitment season was from February to September.

Mortality rate and exploitation level of *P. indicus* shrimp

Total mortality rate (Z) describes the total mortality level, both due to fishing mortality (F) and natural mortality (M). The calculation result showed that Z value of male shrimp was 3.62/year, M was 1.67 and F was 1.84 (Figure 7). Exploitation rate (E = F/Z) obtained the value of 0.52. The optimum value of E was 0.5. Thus, it can be stated that E of *P. indicus* was slightly larger and almost optimum. The total mortality rate of female shrimp was 5.03/year, M was 1.51/year and F was 3.52/year. Based on these calculations, the exploitation rate of female shrimp was 0.70/year. This indicates that the exploitation rate of female shrimp was above the optimum or overfishing. These facts show that female shrimp obtained greater exploitation pressure than the male one.

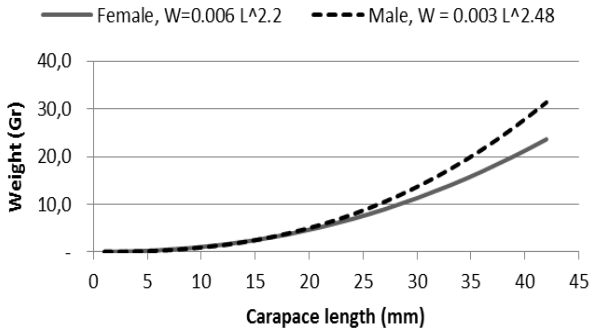

Figure 3. Length-weight relationship curve of *Penaeus indicus* in northern coastal waters of Western Central Java, Indonesia

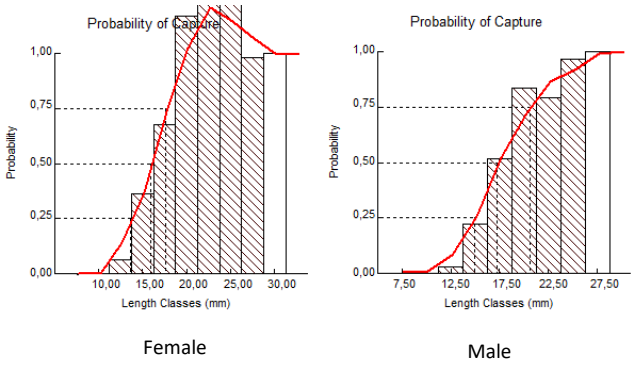

Figure 4. Carapace length size curve of first captured male and female *Penaeus indicus* shrimp

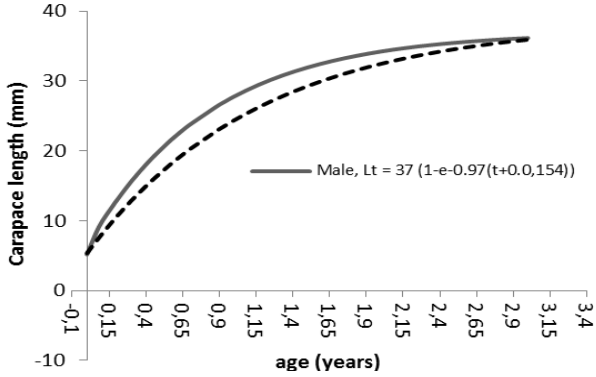

Figure 5. *Penaeus indicus* shrimp growth curve in the northern coastal waters of Western Central Java, Indonesia

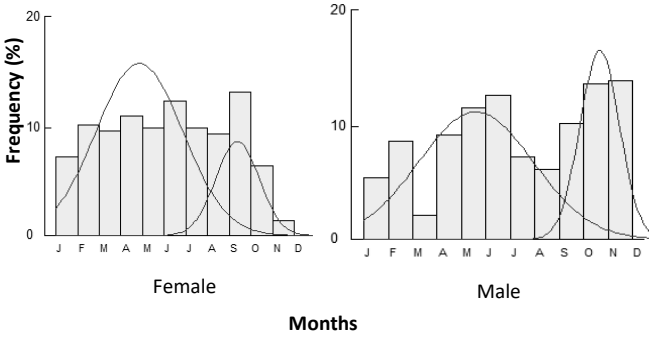

Figure 6. Recruitment pattern of male and female *Penaeus indicus* shrimp in the northern coastal waters of Western Central Java, Indonesia

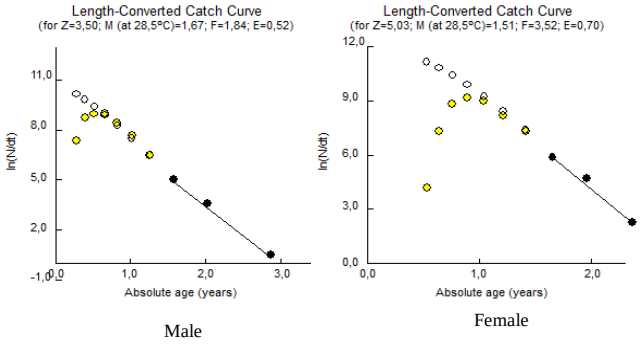

Figure 7. Length-converted catch curve to estimate total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) of *Penaeus indicus* in the northern coastal waters of Western Central Java, Indonesia

Discussion

The K value of *P.indicus* in this study was 0.97 (male) and 0.85 (female). This value was lower than that of the same species in the waters at Rekawa Lagoon, Sri Lanka (K value = 1) (Nissanka's 1997); in the waters of Sofala Bank, Mozambique, (K = 0.89 (female) and K = 1.18 (male)), (Silva and De Sousa ,1992), . (in Manila Nay waters, K value of male= 1.2 and female =1) (Agasen and Del Mundo 1988); in Segara Anakan Lagoon of Cilacap, Indonesia (K=1.26) (Saputra 2008). However, Other studies obtained higher K value, such as in Arabian Sea of Oman obtained K value = 2.21 (male) and K = 1.78 (female), Mehanna et al. (2012). in the Western Coastal Waters of Sri Lanka obtained K value = 1.51 (male) and K=1.87 (female). Jayawardane et al. (2002[a]) In addition, K is the index describing the time it takes to reach the L_∞ length. Based on the analysis of recruitment pattern time, *P.indicus* have a recruitment pattern time throughout the year, with bimodal recruitment peak in April-June as the first peak, and in September-November as the second peak (female shrimp). This is in accordance with the study of Jayawardane et al. (2002[b]) in the Western Coastal Waters of Sri Lanka that *P.* indicus recruitment pattern to the lagoon and offshore environment show two peaks of different, namely March and September (in Lagoon) and April and September (offshore areas). Nissanka (1997) study on *P. indicus* at Rekawa Lagoon, Sri Lanka showed recruitment peak in May and October. Many studies of *Penaeus* genus have a throughout the year recruitment pattern, either with one or two recruitment peaks. *P. merguiensis* in coastal Tarakan has peak recruitment occurring in May (Kembaren and Suman 2013). Gentle and Amiye (2016) reported a throughout the year recruitment peak from May to October. Komi and Francis (2016) also found that *P.monodon* recruitment pattern in the waters of the Andoni River System, Niger Delta Region of Nigeria occurs throughout the year, with the recruiting season occur during the rainy season, and the peak is June. Moreover, Momeni et al. (2018) reported that *P. merguiensis* shrimp in Hormoz Strait, Persian Gulf has a year-round recruitment pattern, with peak from July to November.

Total mortality rate (Z) of *P. indicus* in the Western Coastal North Central Java Sea is high, especially for male shrimp (Z = 5.03/year). Compared to the other studies to the same species, the Z value of this study is higher than in Segara Anakan Cilacap (Z = 3.95/year) (Saputra 2008), in the waters of Sofala Bank, Mozambique (Z = 4.95) (Silva and De Sousa 1992), and in the waters of Rekawa Lahoo, Sri Lanka (Z = 4.93/year) (Nissanka 1997). The high rate of total mortality is due to the high captured mortality rate (F). Consequently, the exploitation rate is high. The capture mortality rate of *P. indicus* shrimp is 4.38/year and the rate of exploitation (E) is 0.7/year (female). This indicates that the exploitation rate of *P. indicus* has been above the optimum limit (E = 0.5).

Based on the size structure of the captured shrimp in the study, it is seen that the catch is dominated by small-size shrimp. This is because in the coastal fisheries dominantly captured by *arad, dogol* and *sodo* fishing gears, has a very small mesh size (0,75 inch). The carapace length of first captured (CLC) of male shrimp is 18.3 mm, while the female shrimp is 17.6 mm. In other studies, Saputra (2008) obtained the CLC value of 20.4 mm in Segara Anakan Lagoon, Cilacap, Indonesia, and Mehanna et al. (2012) indicated the CLC of 22 mm (female) and 23.4 mm (male) in the waters of the Arabian Sea.

Information on the carapace length of first captured (CLC) and the first mature is very important as the foundation in fisheries management. The CLC50 of female shrimp is 17.6 mm. This value is smaller when compared to CLm50 value. Champion (1988) stated that *P.indicus* in South African waters reaches adult at 22-30 mm carapace length, and the first mature gonad (Lm50) is at 25 mm quality length. Jayawardane et al. (2002[b]) obtained *Fenneropenaeus indicus's* first male mature gonad (CLm) at 34 mm carapace length, and 39 mm for female shrimp in the waters of the West Coast of Sri Lanka and Teikwa and Mgaya (2003) in coastal waters of Bagamoyo, Tanzania. Amanat and Qureshi (2014), got the first total length of mature gonad (Lm) of 134 mm in the waters of Sonmiani Bay Lagoon, Balochistan, Pakistan. Trust and Qureshi (2011) get Lm of 133.3 mm or at a carapace length at about 34.5 mm (TL = 30.17 + 3*CL) in the same of waters. These results indicate that *P.indicus* captured in the northern coastal waters of Central Java is still small and young. The size of CLc = 17.6 mm means the shrimp captured has never reached mature gonad period. This consequently can lead to growth overfishing and cessation of new stocks creation. This condition will also lead to the depletion of shrimp parent stock, which automatically will result in a decrease in recruitment. This means that it will cause a decrease in stock which eventually will result in a decline in capture result per trip (CPUE).

Based on the results and discussion above, it can be concluded that (i) the K value of *P. indicus* shrimp is relatively smaller than other waters, which means that the growth rate of *P. indicus* shrimp in the waters of North Central Java is faster; (ii) the recruitment patterns occurs twice a year as in other waters ; (iii) The total mortality rate (Z) of *P. indicus* in the northern coastal waters of Central Java is higher than other waters, mainly due to the high

fishing mortality; (iv) The exploitation status of *P. indicus* shrimp has exceeded the optimum limit.

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