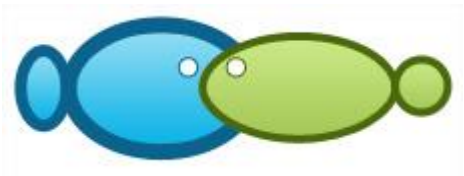

The growth rate of *Fenneropenaeus indicus* in Seneboy Waters, South Sorong, Papua, Indonesia

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Abstract. *Fenneropenaeus indicus* is one of the economically important species of shrimp cultivated in South Sorong Seneboy waters and currently its production tends to decrease. Studying its biological aspects provides data and information needed for assessing its exploitation and managing its conservation. This study aimed to examine the biological aspects of *F. indicus* as a material for shrimp fisheries management in the waters of Seneboy, South Kalimantan. The study was conducted between January-November 2016 in the waters of Seneboy. The results showed that the average size of the caught female *F. indicus* was 13.2-52.8 mm carapace length (CL), with a mode size of 31.1-33 mm CL, and the average size of male was 16-49.6 mm CL with a mode size of 29-31 mm CL. The sex ratio of male and female shrimp was 1:1.8. *F. indicus* spawning season is suspected to last all year and peak in February and October. The average size of the first time caught (Lc=31.1 CL) shrimp was smaller than the average size of the first time cooked gonads (Lm=35 mm), so that most of the shrimp caught were small and had not spawned. In female *F. indicus*, the growth rate (K), asymptotic carapace length (CL) and age at length 0 (t0) were of: 1.1 cm year^{-1}, 54.6 mm CL and -0.14883 years, respectively, while in male they were of: 1.0 cm year^{-1}, 52.6 mm and -0.136202 years, respectively. The natural mortality rate (M), death rate due to capture (F), total death rate (Z) and exploitation rate (E) of female rock lobsters were 2.64 cm year^{-1}, 1.53 cm year^{-1}, 2.64 cm year^{-1} and 0.48 cm year^{-1}, respectively, while in male *F. indicus* amounted to 2.64 cm year^{-1}, 1.42 cm year^{-1}, 1.22 cm year^{-1} and 0.56 cm year^{-1}, corresponding to an optimal utilization of the *F. indicus* resources. The status of *F. indicus* in Seneboy waters is "not fully exploited".

Key Words: biology aspect, shrimp fisheries management, sex ratio, spawning season.

Introduction. *Fenneropenaeus indicus* is one of the important commodities in the waters of Seneboy, South Sorong. *F. indicus* has economic value and contributes to the improvement of the fishermen's life in South Sorong. Seneboy fishermen catch *F. indicus* using a 4 m nylon trammel net as fishing gear, operated by 3 people from vessels of about 6 m in length, made of wood and fiber, of an average tonnage of 3 GT and a main engine power of 15 HP. The mesh size is of 1.5-7.25 inch, with a polyethylene head rope of Ø 8 mm. The length of the ground rope is 660 m. This effective and environmentally friendly fishing gear is used for catching *F. indicus* and other types of demersal fish which are bycatch (BRPL 2016). The catching time per trip ranges from 6 to 9 hours (from 07.00 to 16.00 hours, which is one day fishing) and the fishing ground ranges from 1 to 20 miles, with a distance of about 1-4 hours from the landing base. The shrimp fishing grounds are located around Wawonket Cape, Dua Island, Daram Island, Sibabu Cape, Komokara Cape, Sabuga Island, Sele Cape, Misool Islands, Sinabu Cape, Banana Island and Segeat Island. The shrimp

fishing season is 12 months with the highest season in July-November, with a catch of around 10-100 kg trip^{-1}. The production of shrimp and other crustaceans in South Sorong waters, in the period 2009 to 2016, reached 4,051 tons, with an annual average of 506.42 tons or 38.75%, total production. The annual average production of *F. indicus* was 475.75 tons, with the highest production in 2010 of 557 tons and the lowest in 2013 of 350 tons (DKP Sorong 2017).

Shrimp catching activity in Seneboy, South Sorong, is the main support to meet the economic needs of trammel net fishermen in Temibuanan Regency. Catching shrimp at this location is carried out very intensively, so that fishing activities need to be supervised. The biology and population parameters provide the control and management criteria to the marine authorities. Research on several aspects of biology and population parameters was extensively conducted in several waters in Indonesia: Arafura (Naamin 1984), Cilacap (Suman 1992; Suman & Boer 2005; Hargiyatno et al 2013; Saputra & Subiyanto 2007), Strait Madura (Setyohadi et al 1999), Kotabaru (Suman & Umar 2010), Bone (Kembaren & Ernawati 2015), Tarakan (Kembaren & Suman 2013) and Meulaboh (Yusuf et al 2017).

The study provides information on the exploitation status of *F. indicus*, facing the market demand and an increasing commercial value. Rational management actions need to be taken in order to maintain a sustainable balance of the shrimp resources and the population parameters estimation is required as supporting data and information. The results of this study are expected to complement and update previous studies, underlying the management of *F. indicus* resources in the waters of Seneboy, South Sorong, and surroundings.

Material and Method

Research location and time. *F. indicus* sampling was carried out with a trammel net, obtained from fishermen and shrimp collectors in Seneboy Temibuana, South Sorong, from January to October 2016. The enumerators were taking samples using a random sampling method. The data collected included carapace length (CL), weight, sex, gonad maturity level and fishing area (Figure 1).

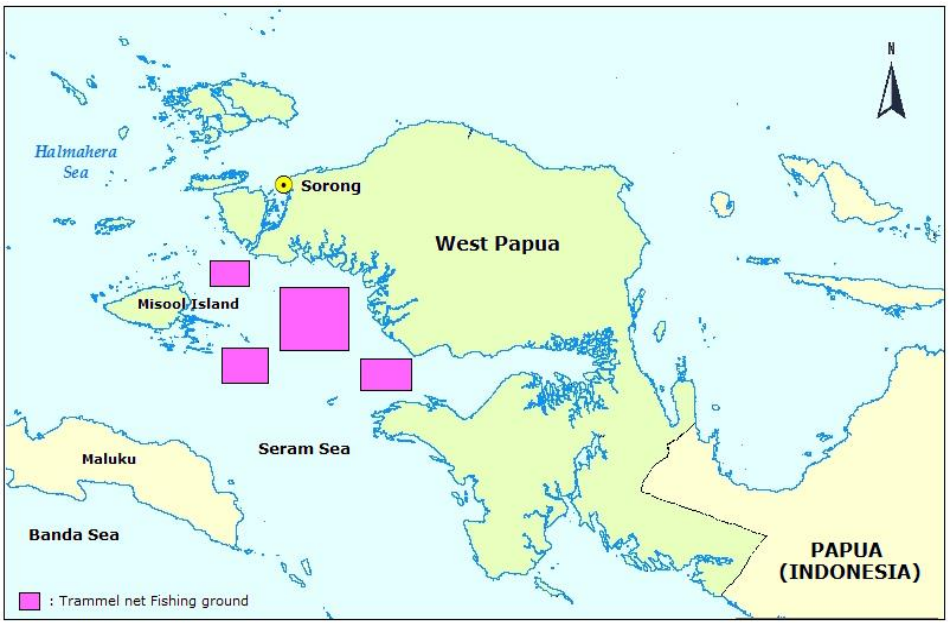

Figure 1. Fishing ground of trammel net in Seneboy, South Sorong (https://www.mapsofworld.com/where-is/sorong.html).

Data analysis. Biological data analysis included the size distribution, sex ratio, gonad maturity level, average size of first caught specimens (Lc). The analyzed population parameters were the growth pattern (CL∞, K), mortality parameters (Z, M, F) and utilization rate (E). The distribution of carapace length measurements is presented in the form of a bar chart with a length class of 2 mm. The level of maturity of female *F. indicus* gonads was observed visually based on Motoh (1981), namely by looking at the size of the shrimp ovary, located on its back. Shrimp sex ratios were analyzed using the Chi-square test (Walpole 1993).

The length at first matured (Lm) is obtained by entering the carapace length and P_{Lm} values into a graphical logistic function (King 1995), using the following equation:

$$P_{Lm} = \frac{1}{1 + \exp\ (aCl + b)}$$

Where:
P_{LM} – logistic curve of proportion mature by length, Lm was determined by a/b;
a - the intercept of regression;
b - the slope of regression;
CL - the length of shrimp carapace.

The value of carapace length caught for the first time (Lc) is obtained through a logistic function approach, with the Sparre & Venema (1992) equation:

$$S_L = \frac{1}{1 + \exp\ (a - b * CL)}$$

Where:
S_L - logistic curve and Lc was determined by a/b;
a - the intercept of regression;
b - the slope of regression;
CL - the length of shrimp carapace.

The method used in the study of population parameters is an analytical model based on the composition of the age structure of the shrimp (Sparre & Venema 1992). The growth parameters of Von Bertalanffy, namely the asymptotic carapace length (CL∞) and the growth coefficient (K) were estimated by the ELEFAN I program in the FISAT II program (Gayanilo et al 2005). An estimation of the theoretical age (t0) was carried out with the Pauly's (1983) empirical equation, namely:

$$Log\ (-t_0) = (-0.3922) - 0.2752 \log CL\infty - 1.038 \log K$$

The value of the natural mortality (M) is estimated through the Pauly's equation, by including the effect of the mean water temperature (T) on the mortality rate, based on empirical observations (Pauly et al 1984):

$$\text{Log M= (-0.0066)-0.279 log CL}\infty\text{+0.6542 log K +0.4634 Log T}$$

The total mortality (Z) value was estimated using the length-converted catch curve method in the FISAT II program package (Pauly 1983; Gayanilo et al 2005). The capture mortality and exploitation rate are estimated using the Sparre & Venema (1992) equations:

$$E = \frac{F}{F + M}$$

$$E = \frac{F}{Z}$$

Where:
E - the exploitation rate;
F - the Fishing mortality;
M - natural mortality;
Z - the total mortality.

Results and Discussion

Biological aspects. A number of 2,085 *F. indicus* specimens were collected during the study were: 1,174 females (56.31%) and 911 males (46.69%). The carapace length of female *F. indicus* ranged from 13.2 to 52.8 mm, for a weight ranging from 9.6 to 88.4 g, with two modes in the ranges of 29-31 and 31.1-33 mm CL. The carapace length of male *F. indicus* ranged between 16-49.6 mm, for a weight ranging from 15.4 to 78.6 g, with a mode in the range of 29-31 mm CL (Figure 2).

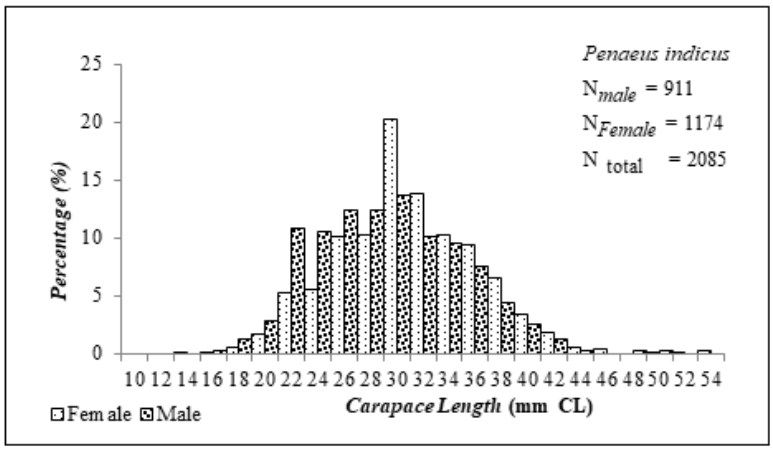

Figure 2. Length frequency of *Fenneropenaeus indicus* in Seneboy waters.

The sex ratio determination of *F. indicus* in the waters of Seneboy South Sorong is based on the chi squared test, which indicates an imbalance between the male and female shrimp populations: in most cases, female shrimp dominate the catch. Although the average sex ratio of *F. indicus* males and females was 1:1.78, it showed a balanced value of 1:1 in February, March, September and October (Table 1).

Table 1

Sex ratio of *Fenneropenaeus indicus* in Seneboy waters, January-October 2016

Months	*Sex ratio of F. indicus*					*Comparison*
(2016)	*Male*	*Female*	*M:F ratio*		*X2*	*P=95%*
January	66	162	1	2.45	40.42	Not balanced
February	100	98	1	1.48	0.02	Balanced
March	94	106	1	1.61	0.72	Balanced
April	78	99	1	1.50	2.49	Not balanced
May	149	97	1	1.47	10.99	Not balanced
June	56	144	1	2.18	38.72	Not balanced
July	100	161	1	2.44	14.26	Not balanced
August	62	138	1	2.09	28.88	Not balanced
September	119	81	1	1.23	7.22	Balanced
October	87	88	1	1.33	0.01	Balanced
Total	911	1174	1	1.78	143.73	Not balanced

The highest proportion of mature female *F. indicus* (the maturity level of gonads III and the maturity level of gonads IV) was in January, February, September and October, with the peak maturing of gonads in October. The proportion of females with mature gonads in January, February, September and October was 60, 44, 46 and 40% (Figure 3).

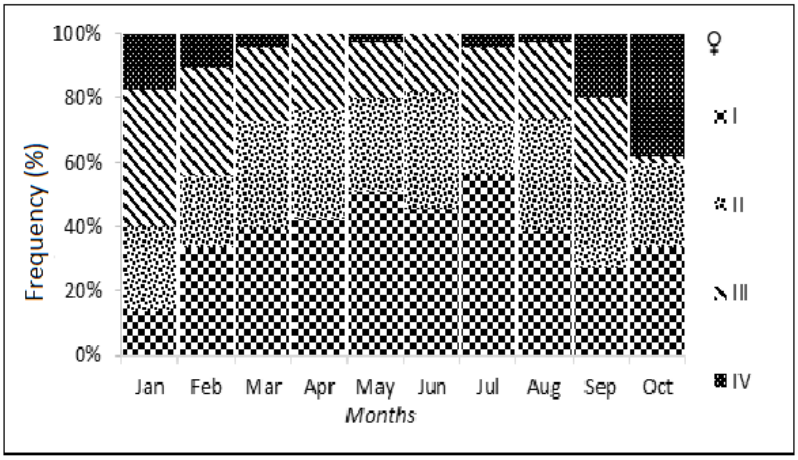

Figure 3. Proportion of *Fenneropenaeus indicus* females with mature gonads in Seneboy waters, January-October 2016.

The size of the first time capture (Lc) corresponds to the probability level of L50% of the trammel net selectivity, meaning that the catch distribution of *F. indicus* can influence the availability of resources. The logistic function graph with a class interval of 2 mm CL indicates that the average value at the first capture of *F. indicus* is 31.1 mm CL, with an average value (Lm) of 35 mm CL at the first gonad maturation (Figure 4).

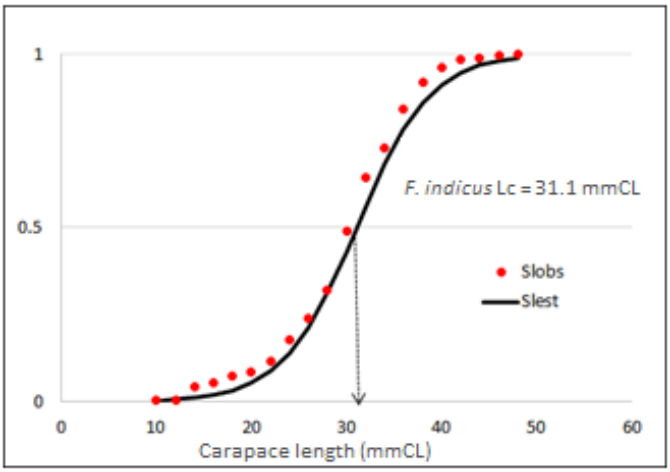

Figure 4. Average length at first *Fenneropenaeus indicus* capture with a trammel net.

Population parameters. The growth parameters of *F. indicus* in the Seneboy waters is processed from long frequency distribution data carapace by tracking any mode shift the distribution of carapace length frequencies in a curved sequence of times Von Bertalanffy's growth. Based on the results of the analysis, it was found that infinitive carapace length (L∞) of female *F. indicus* was 54.6 mm, the growth rate (K) was 1.1 year $^{-1}$ and the male was 52.6 mm, the growth rate was 1.0 year^{-1} (Figure 5). From the value of these two parameters a growth equation and a key relationship can be created between carapace lengths with aged shrimp by using multiple variations in age value (t).

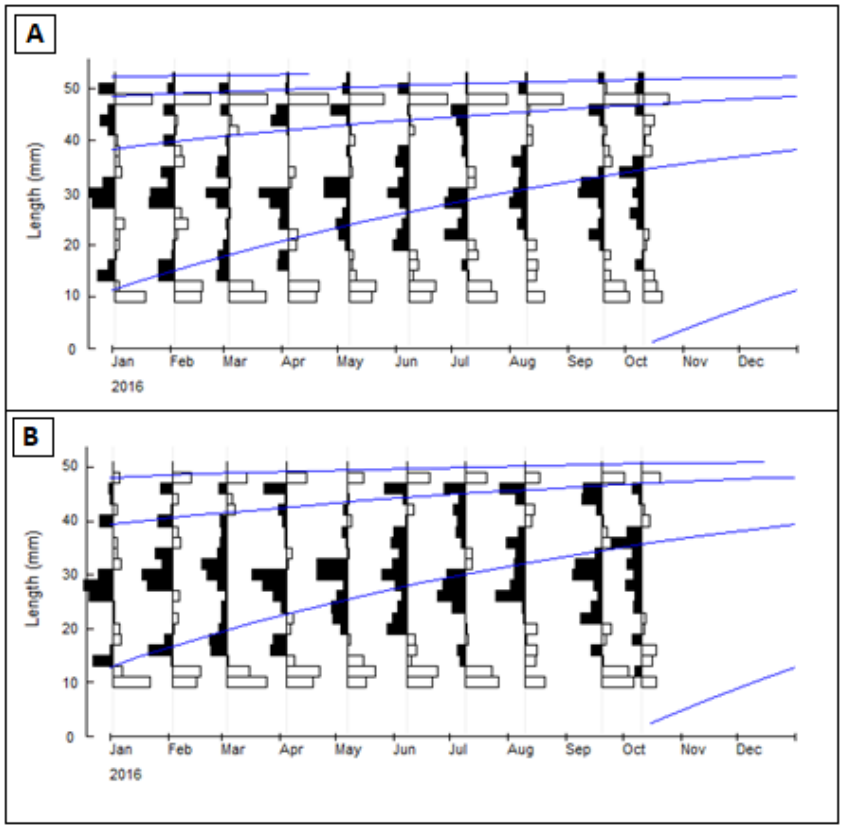

Figure 5. Growth model of male (A) and female (B) *Fenneropenaeus indicus* by ELEFAN I in Seneboy waters.

The asymptotic carapace length (L∞) of female *F. indicus* was 54.6 mm CL and 52.6 mm CL for males, while the age of female *F. indicus* at 0 (t0) was -0.14883 years and -0.136202 for males. So that the equation for the Von Bertalanffy equation for female *F. indicus* is Lt=54.6 (1-e-1,100 (t-0.14883)) and for male it is Lt=52.6 (1-e-1.00 (t-0.136202)) (Figure 6). The maximum size range of *F. indicus* is estimated at the age of 1.8 years or around 20 months. The average size of 31.1 mm CL in caught *F. indicus* (Lc) was estimated at the age of 7-8 months. The average mature gonad size in females (Lm) was of 35 mm CL, at the age of 9-10 months.

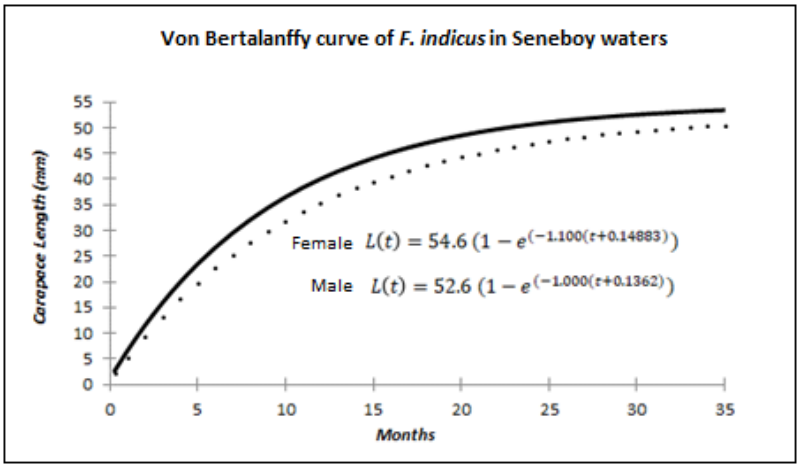

Figure 6. Von Bertalanffy curve of *Fenneropenaeus indicus* in Seneboy waters.

The total mortality rate (Z) of female and male *F. indicus* based on the length-converted catch curve is 3.16 year^{-1}, with a natural mortality rate (M) of 1.64 year^{-1} and the mortality rate due to fishing (F) of 1.53 year^{-1}. The total mortality rate of male *F. indicus* was 2.64 year^{-1}, the natural mortality rate was 1.42 year^{-1} and the mortality rate due to fishing was 1.22 year^{-1}. Based on these mortality parameters, the utilization rate of *F. indicus* was 0.48 for females and 0.46 for males (Figure 7).

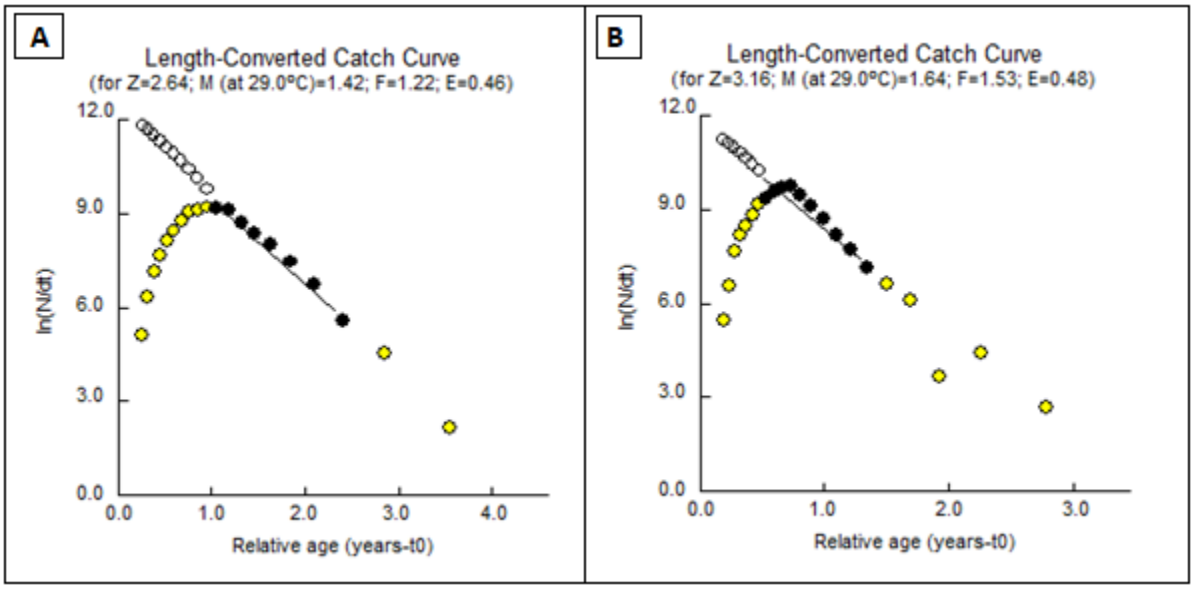

Figure 7. Growth curve of male (A) and female (B) *Fenneropenaeus indicus* in waters of Seneboy.

Discussion. The size distribution of *F. indicus* caught in the study area was greater than in Kaimana waters, ranging from 25-49 mm, and the average size was 28.98 mm for males and 34.96 for females. The size of *F. indicus* specimens caught in Meulaboh waters ranged between 17.8 and 79.54 mm for females and between 18.3 and 64.36 mm for males. The size of *Penaeus merguensis* in Central Java waters ranged between 20 and 62 mm for males and between 14 and 68 mm for females, and averaged 17 to 47 mm in West Java waters (Tirtadanu& Panggabean 2018; Yusuf 2017; Suman et al 1988). Differences in shrimp size at several locations can be caused by different gears, environmental conditions and fishing pressure (Olin et al 2017; Wilson et al 2010; Matthews 1982; Ogbonna 2001). Given the larger shrimp size in Seneboy waters, it is supposed that the species is not over-utilized.

The sex ratio of male and female shrimp in the study area was not balanced: the females dominated the catch. The unbalanced sex ratio is similar to the *F. indicus* caught in Meulaboh waters (Yusuf 2017; Saputra 2008; Saputra et al 2013; Wedjadmiko & Yulianti 2003; Wedjatmiko 2009; Suman et al 1991), suggesting that the fishing pressure of shrimp resources in Seneboy waters has not disturbed the population renewal so that the sustainability of shrimp stocks is still well maintained.

The peak indicated that a higher frequency of mature gonads in *F. indicus* occured in February and October, suggesting the spawning seasons for the shrimp (Martosubroto 1978). For comparson, the spawning peaks occurred in November for several types of Penaied shrimp from the waters of West Kalimantan (including *P. merguiensis*), in January and August for the *Metapenaeus monoceros* from the Southern Java waters and from September to October for the *M. monoceros* from the Gulf of Carpentaria, Australia (Kembaren & Suman 2013; Suman et al 2005; Crocos et al 2000; Pillai & Thirumilu 2013; Gerami et al 2013). The spawning season for *F. indicus* in the study area lasted throughout the year, with peaks in February and October. Therefore, from the perspective of the

resources sustainability, it is preferable to suspend the *F. indicus* fishing activities in Seneboy waters during February and October.

The first catch average size (Lc) of *F. indicus* in the study area was of 31.1 mm CL and the mean value at the first gonad maturity was 35 mm CL. The results of research conducted in the waters of the Cilacap Segara Anakan Lagoon, using floating nets, showed an Lc value of 20.2 mm, for a total length of about 90 mm (Saputra 2008). Chan (1998) stated that *F. indicus* females can reach a total length of 230 mm, although they generally measure less than 170 mm. These results are different from the research conducted in the waters of North Central Java, where the carapace length of *P. merguensis* was of 29.4 mm (Tirtadanu & Ernawati 2016), the carapace length in the Mayangan waters was 28.9 mm (Wedjatmiko & Yulianti 2003) and the Lc in the Dolak waters, Arafura Sea was 28.78 mm (Hargiyatno & Sumiono 2012). The differences of Lc values are not only caused by the mesh size of the net used, but they are also due to the operations duration and to the location of the fishing ground. The differences of Lc values are not only caused by the mesh size of the net used, but they are also due to the operations duration and to the location of the fishing ground. According to Susetiono & Setyono (1990), the *P. merguensis* from shallow waters tends to be smaller than in deeper waters (e.g. Cilacap), with an average size (Lc) of 51 mm CL (Saputra et al 2013). The shrimp size differences at several locations can be caused by different gears, environmental conditions and fishing pressure (Olin et al 2017; Wilson et al 2010).

According to FAO (2008), the Lm value is 50% of *F. indicus*, at a total length of 130-149 mm. This shows that the value of L50% <Lm50% means that *F. indicus* recruitment is threatened by overfishing. According to Teikwa & Mgaya's (2003) research, the *F. indicus* carapace length size of the first caught males is of 34 mm and 39 mm carapace in female shrimps. The results of a study conducted by Melmammblessy (2011) indicated that in the Arafura waters, the average size of the first catch (Lc) had a carapace length of 60.26 mm. The average size of the *F. indicus* caught for the first time (Lc) in the study area was smaller than the average size at the first maturity of gonads (Lm), indicating that most of the shrimp caught had not spawned. In the long term, this situation is detrimental to the population's sustainability, hampering the shrimp's recruitment process in the Seneboy waters. In this regard, it is necessary to adjust the size of the mesh in such a manner that the smallest carapace length of the caught *F. indicus* cannot be under 13.2 mm CL.

The growth rate (K) of *F. indicus* in the research area shows that they have a fast growth rate: 1.1 year^{-1} in females and 1.0 year^{-1} in males, with an asymptotic carapace length (L∞) of 54.6 mm CL for females and 52.6 mm CL for males. The growth parameters in different locations were: L∞=35.7 mm and K=1.26 year^{-1} in the waters of the Segara Anakan Lagoon Cilacap, 1.4 year^{-1} and L∞ 44.3 mm in the Kota Baru waters and 44.7 mm CL for males and 51.25 mm CL for females in the Kaimana waters (Table 2).

The mortality rate (Z) of *F. indicus* in the Seneboy waters is relatively low, namely 3.16 in males and 2.6 in females. Some *Penaeid* shrimp in other waters, namely the waters of the Cilacap Segara Anakan Lagoon, obtained an M value of 2.6 cm year^{-1}, an F value of 1.35 cm year^{-1} (*P. meruiensis* in Segara Anakan Lagoon Cilacap is 1.43 year^{-1}, the natural mortality rate is 1.85 cm year^{-1} and catching 2.32 cm year^{-1}, Madura waters natural mortality rate of 2.17-2.22 cm year^{-1} and catching 1.11-1.56 cm year^{-1} (Saputra 2008; Kembaren et al 2012; Setyohadi et al 1999; Hedianto et al 2016).

The highest mortality rates (ind year^{-1}) were recorded: 9 for males and 9.47 for females in the waters of Kota Baru, 10.58 in the Kakinada waters, 7.01 in the Khoozestan waters and 5.78 in the Vietnamese waters (Tirtadanu et al 2017; Devi 1987; Ansari et al 2014; Dinh et al 2010). The natural mortality is influenced by several factors such as food availability, disease, environment, competition and the presence of predatory species (Sparre & Venema 1992; Niamaimandi et al 2007). *Penaeid* prawn is the prey of several demersal fish, such as *Lutjanus gibbus*, *Eleutheronema tetradactylum* and *Arius* sp. (Bachok et al 2004; Titrawani et al 2013). Death due to fishing (F) of both male and female *F.*

indicus is lower than the natural mortality rate (M), indicating that the *F. indicus* population has not been exploited intensively by fishermen in the waters of Seneboy, West Papua. Garcia (1988) suggests that the average natural mortality rate (M) of penaeid shrimp is 2.4±0.3 year^{-1} for adult shrimp. Naamin (1984) found that the F value of *P. merguensis* in Arafura waters varies according to the development of the fishing effort, ranging from 0.55 year^{-1} (at the start of the exploitation) to 8.99 year^{-1}.

Table 2

Asymptotic length (L∞), growth rate (K) and exploitation rate (E) of *Fenneropenaeus indicus* in some areas

Location	*Sexes*	$L_{\infty\ (mm\ CL)}$	*K*	*t0*	*Authors*
Cilacap, Central Jawa	Combined	35.7	1.26	-	Saputra (2008)
Kota Baru, South Kalimantan	Combined	44.3	1.4	-	Suman et al (2010)
Kaimana, West Papua	Combined	44.7	1.38	-	Tirtadanu & Pangabean 2018)
Cilacap, Central Java	Male	40.7	1	0.56	Suman & Prisantoso (2017)
	Female	54.2	1.1	0.36	
Tarakan, North Kalimantan	Male	45.2	1.55	0.76	Chodrijah & Suman (2017)
	Female	57.6	1.33	0.76	
Sampit, Central Kalimantan	Combined	57.8	1.45	0.66	Nurdin & Kembaren (2015)
Tanal Laut, South Kalimantan	Combined	55	1.05	0.74	Suman et al (2017)
Cenderawasih Bay, Papua	Male	44.5	1.05	0.66	Kembaren & Ernawati (2015)
	Female	48.7	1.15	0.55	
Kaimana, West Papua	Male	44.7	1.4	0.49	Tirtadanu & Panggabean (2018)
	Female	51.25	1.37	0.44	
Seneboy, West Papua	Male	54.6	1.1	0.148	Present research
	Female	52.6	1.0	0.136	

In this study, the exploitation rates (E) of female and male *F. indicus* were 0.48 and 0.46. This condition explains that the fishing rate is greater than the natural mortality rate. The optimum exploitation rate stated by Gulland (1983) is 0.5, so that the rate of exploitation of *F. indicus* in Seneboy waters is close to the optimum value and is still sustainable. The level of exploitation of *F. indicus* in several areas has exceeded the optimum limit, namely in the waters of the Segara Anakan Cilacap Lagoon, Meulaboh waters, Tarakan Bay, Tanah Laut and Cenderawasih, where the level of exploitation indicates overfishing (Saputra 2008; Yusuf et al 2017; Chodrijah & Suman 2017; Suman et al 2017; Kembaren & Ernawati 2015). The exploitation of *F. indicus* has approached the maximum, suggesting that a reduction of the fishing pressure is required, with at least 5% of the current total effort.

Conclusions. The average size of *F. indicus* caught in the waters of Seneboy South Sorong is 16-49.6 mm CL for the males and 13.2-52.8 mm CL for the females. The sex ratio of *F. indicus* is unbalanced: 1:1.8, male against female. The spawning season lasts throughout the year with peaks in February and October. The catch is dominated by adults so that management sets the regulations for the minimum legal size. These results concluded that the arrest of *F. indicus* can be continued by arranging the arrest effort and stipulating a minimum legal size of 35 mm CL. This indicates that the level of exploitation of *F. indicus* in Seneboy waters is not yet optimal, but leads to overfishing. In order to maintain the sustainability of the *F. indicus* resources in the waters of Seneboy, West Papua, it is advisable (1) to reduce efforts with about 5% from the current level, by adjusting the mesh in such a manner that the retained catch size of *F. indicus* will be of at least 13.2 mm CL and (2) to suspend the *F. indicus* fishing operations in February and October.

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Bay 2017" which was organized by the Muara Baru Jakarta Marine Fisheries Research Institute.

Conflict of interest. The authors declare no conflict of interest.

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