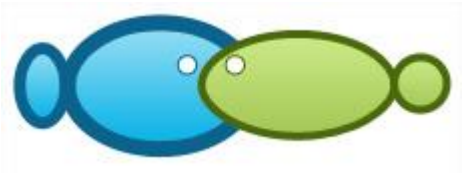

Catch rate and population parameters of banana prawn *Penaeus merguiensis* in Kaimana waters,West Papua, Indonesia

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Abstract. Banana prawn (*Penaeus merguiensis* De Man, 1888) was one of the economically important commodities in Kaimana waters. The fishing of *P. merguiensis* in Kaimana waters is necessary to be managed so the shrimp fishing will be sustainable. One of the important information that was needed for determining the effective management was the study of exploitation status. The aims of this research were to study the exploitation status based on the catch rate and the population parameters. The research was conducted in March-December 2017 in Kaimana, West Papua. Population parameters were analyzed based on the movement of length size with analytical model. The results showed that the catch rate of *P. merguiensis* with trammel net was still high (11.6 kg/trip). The exploitation status of *P. merguiensis* was still sustainable based on the exploitation rate (E) of 0.44-0.49 and spawning potential ratio of 35%. The catch rate of *P. merguiensis* that was still high and the exploitation status that was still sustainable were caused by no trawl gears since 2015 so the trammel net was the only gear that operated for shrimp fishing. Most of shrimps were caught before spawning so it needed the minimum legal size regulation. From this result, it was suggested that the *P. merguiensis* fishing can be continued without reducing the fishing effort with the regulation of just operating the trammel net for shrimp fishing and the minimum legal size was 35 mm.
Key Words: sustainable, exploitation status, shrimp, spawning potential ratio, trammel net.

Introduction. Banana prawn (*Penaeus merguiensis* De Man, 1888) was one of the potential fisheries commodity that was exploited in Kaimana waters. Kaimana waters was part of the Arafura Sea where the exploitation level has reported as overfished in 1980 (Naamin 1984). The fishing gear that was used for catching shrimp before 2015 was trawl, but after 2015, the shrimp fishing used trammel net because the government banned trawler in some areas of Indonesia. There are 4.072 units of trammel net vessel that was operated in West Papua (DGCF 2015) and its fishing needed the information of exploitation status because the high fishing pressure without the management could decrease its stock. The method that could be used to study about its exploitation level was the analytical model.

The stock assessment of *P. merguiensis* by analytical model was reported in some areas in Indonesia and the exploitation rate was reported as overfished in Tanah Laut and Tarakan waters (Suman et al 2017; Chodrijah & Suman 2017). The research related to the fishing of *P. merguiensis* in Papua was reported as overfished in Arafura Sea in 1980 and in Cenderawasih bay in 2013 (Naamin 1984; Kembaren & Ernawati 2015). Rozaki et al (2014) reported that the yields of shrimp fishing by trawl were correlated to the depths in Kaimana waters. The information about stock density of *P. merguiensis* in Papua was reported in 2008 and the stock density was 0.19 kg/km^2 (Hargiyatno et al 2013). Some of that research was related to the catch rate by trawl and the exploitation status when the trawl was still operated. The catch rate and exploitation status of *P. merguiensis* in 2015 when trawl was banned, hasn't reported yet so the catch rate of trammel net as the dominant gear for *P. merguiensis* and its exploitation status was important information as basis of sustainable shrimp fisheries management in Kaimana.

This study was analyzing the catch rate of trammel net and the population parameters of *P. merguiensis* in Kaimana waters. The information of catch rate by trammel net was needed to evaluate the effectivity of trammel net. The population parameters were determined for knowing the exploitation status after the ban of trawler fishing in 2015. The other information was the length at first maturity (Lm) and the length at first captured (Lc) which was important information for knowing the fishing pressure and the selectivity of trammel net (Lappalainen et al 2016; King 1995). This study was important as basis for developing the sustainable shrimp fisheries management in Kaimana waters.

Material and Method

Description of the study sites. This research was conducted in some *P. merguiensis* inhabiting areas in Kaimana such as Pasarbaru, Tanggaromi and Coa in March – December 2017. Samples were obtained from fisherman who captured shrimp by trammel net which was operated in Kaimana waters (Figure 1).

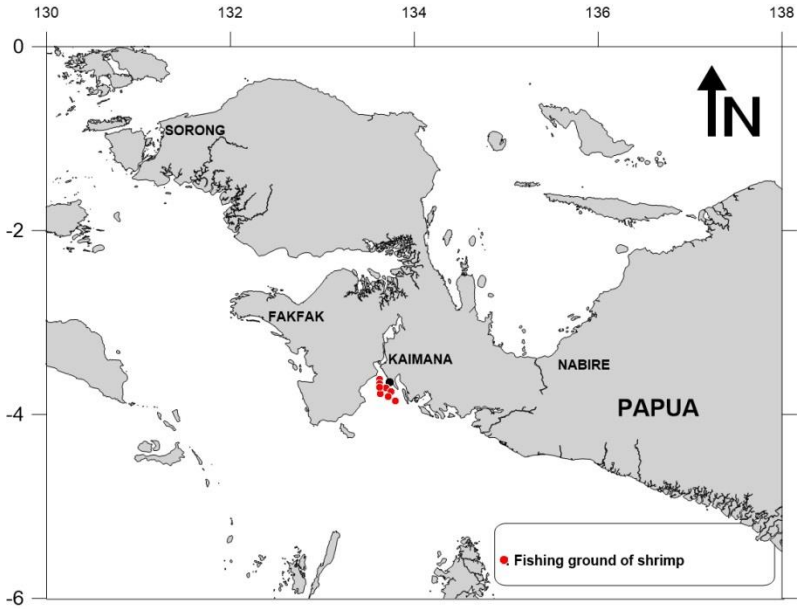

Figure 1. The fishing ground of shrimps by trammel net in Kaimana waters.

Trammel net was one of environmentally friendly fishing gear that was used for catching shrimp (Baihaqi & Hartati 2017). The setting installation of trammel net was about 2 hours at the depths of 5-20 m and the shrimp was caught by pocket and snag (Hufiadi 2008). The size of vessel was LxBxD = 9x1.1x1.8 m with a power of 17 hp. Total trammel net that was used from each vessel was about 20-39 units for each vessel and it was operated in one day fishing. The length of headrope was 18 mm and the height of trammel net was 1.5 m. The inner mesh size was 2 inches and the outer was 6 inches.

Data analysis. The collected data was related on the yields of *P. merguiensis* by trammel net and the biometric measurements included carapace length, sexes and gonad maturity stage. The data was analyzed to determine the catch rate, length frequency, length at first maturity (Lm), length at first capture (Lc), population parameters, exploitation rate and spawning potential ratio. The catch rate was calculated by the equation (Sparre & Venema 1992):

$$CPUE = \frac{c}{f}$$

Where: CPUE = Catch per Unit Effort (kg/trip); c = Catch (kg); f= Effort (trip).
Length frequency was performed by histograms chart with the interval size of 2 cm. The length-weight relationship was performed by the equation of King (1995):

$$W = aL^b$$

Where: W=weights (gram); CL=Carapace Length (cm) and a,b=regression constant.

Estimation of length at first captured (Lc) was determined based on logistic curve by the equation (Sparre & Venema 1992):

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

Where: a=the intercept of regression; b=the slope of regression; S_L=logistic curve and Lc was determined by a/b.

Length at first matured (Lm) was analyzed based on logistic curve by the equation (King 1995):

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

Where: a=the intercept of regression; b=the slope of regression; P_{Lm}= logistic curve of proportion mature by length; Lm was determined by a/b.

Growth parameters including asymptotic length (L_∞) and growth rate (K) were estimated by Electronic Length Frequency Analysis/ELEFAN I in FISAT II packages (Gayanilo et al 2005). Theoretical age when the shrimp has zero length (t_0) was calculated based on the equation of Pauly (1983):

$$\text{Log } (-t_0) = -0.3922 - 0.2752 \text{ log } (L_\infty) - 1.038 \text{ log } (K)$$

The von Bertalanffy growth model was used to fit a curve of mean length and estimated age by following equation of Sparre & Venema (1992):

$$L_t = L_\infty \left[1 - e^{-k(t-t_0)}\right]$$

Where: Lt is the carapace length at age t; L_∞ is asymptotic carapace length (cm); K is the growth rate of shrimp and t_0 is the point in time when the shrimp has zero length.

Total mortality was estimated by applying length converted catch curve in FISAT II packages (Pauly 1983; Gayanilo et al 2005). Natural mortality (M) was estimated by using Pauly et al (1984) formula with 29°C sea surface temperature:

$$\text{Log } (M) = -0.0066 - 0.279 \text{ log } (L_\infty) + 0.6543 \text{ log } (K) + 0.4634 \text{ log } (T)$$

Fishing mortality and exploitation rate was estimated by the equation (Sparre & Venema 1992):

$$F = Z - M \text{ dan } E = \frac{F}{Z}$$

Spawning potential ratio was estimated by Length based SPR and it can be used for estimating the exploitation status of some fisheries commodities (Hordyk et al 2015). The value of SPR will be high if the catch was dominated by big shrimp or the shrimp has spawned and the value of SPR will be low if the catch was dominated by small size (Hordyk et al 2015; Prince et al 2015). The spawning potential ratio was determined by the comparison of the spawning potential in the present of fishing ($SSBR_{fished}$) and the spawning potential in the absence of fishing mortality ($SSBR_{unfished}$) based on the equation of Goodyear (1993):

$$SPR = \frac{SSBR_{fished}}{SSBR_{unfished}}$$

Results and Discussion

Catch rate. The yields of *P. merguiensis* by trammel net from 3,605 fishing trips were 41,775 kg or 41.8 tons. The mean catch rate was 11.5882±0.4 kg/trip. The peak of yields was occurred in August, October and December and the highest catch rate was occurred in August (27.1 kg/trip) (Figure 2). This condition showed that the fishing season was estimated in August, October and December.

The mean catch rate of *P. merguiensis* by trammel net in Kaimana waters (11.6 kg/trip) was higher than the mean catch rate of the same gear in Java Sea (2-3 kg/trip) and the mean catch rate in South Kebumen (2.83 kg/trip) (Dudley & Tampubolon 1985; Linting & Anung 2002). The mean catch rate of banana prawn that was relative high in Kaimana was caused by absence of trawler in Kaimana since 2015 so the trammel net was the only gear for catching shrimp.

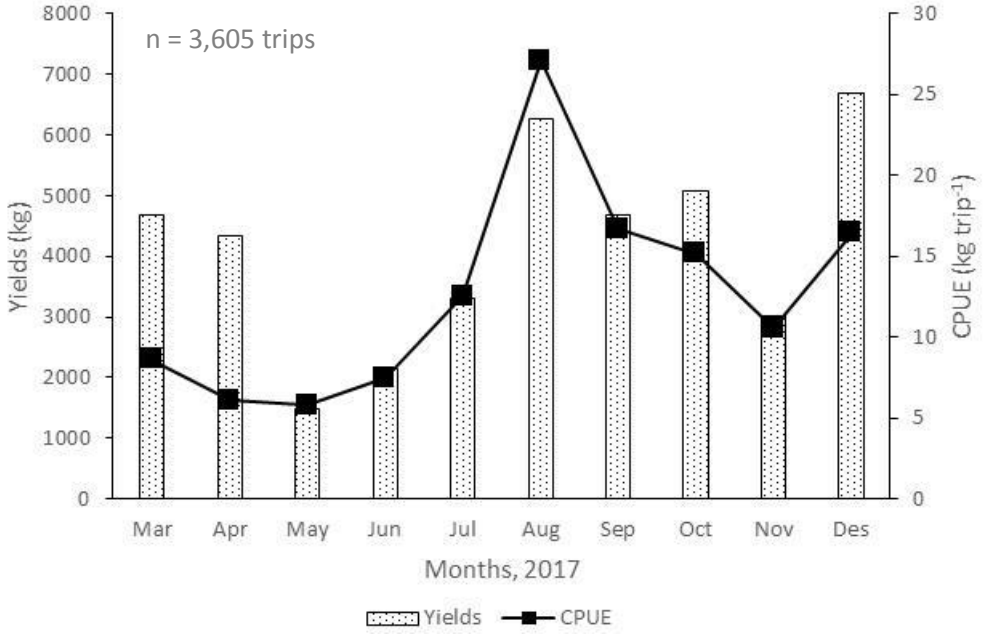

Figure 2. Yields and catch rate of *Penaeus merguiensis* in Kaimana waters, 2017.

Length frequency. The carapace length of *P. merguiensis* in Kaimana ranged between 25-49 mm and the mean size was 28.98 mm for males and 34.96 for females (Figure 3). The size of *P. merguiensis* in Kaimana was bigger than the shrimp that was caught in Kotabaru (14-46 mm) and the size in West Java (17-47 mm) (Tirtadanu et al 2017; Suman et al 1988). The different size of shrimps in some locations could be caused by different gears, environment condition and fishing pressure (Olin et al 2017; Wilson et al 2010). The size of shrimps which was relatively high in Kaimana was caused by the fact that *P. merguiensis* is not overfished yet.

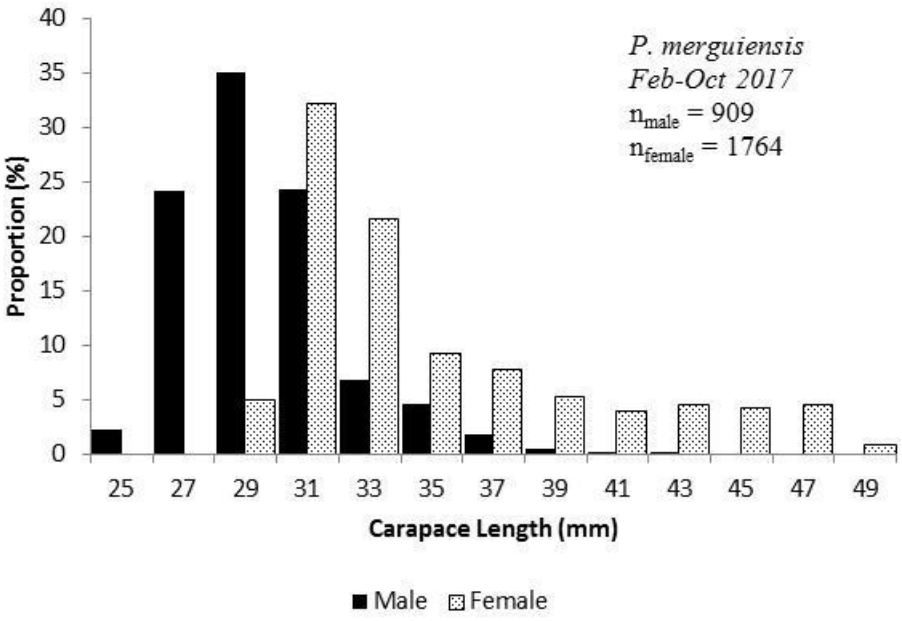

Figure 3. Length frequency of *Penaeus merguiensis* in Kaimana waters, 2017.

Length-weight relationship. The length-weight relationship of *P. merguiensis* in Kaimana waters was followed by the equation of $W=0.0102*L^{2,41}$ for males and $W=0.0403*L^{1,89}$ for females. The growth pattern of shrimp has negative allometry that the value of b was less than 3 (Figure 4). This condition showed that the growth of length was faster than the growth of weights. The negative allometry was found in Kotabaru and Arafura Sea (Tirtadanu et al 2017; Hargiyatno et al 2013). Saputra et al (2013) found an isometric pattern of female *P. merguiensis* in Semarang. The different pattern of growth could be caused by the season, growth, environment and food availability (Anand et al 2014; Udoinyang et al 2016; Primavera et al 1998).

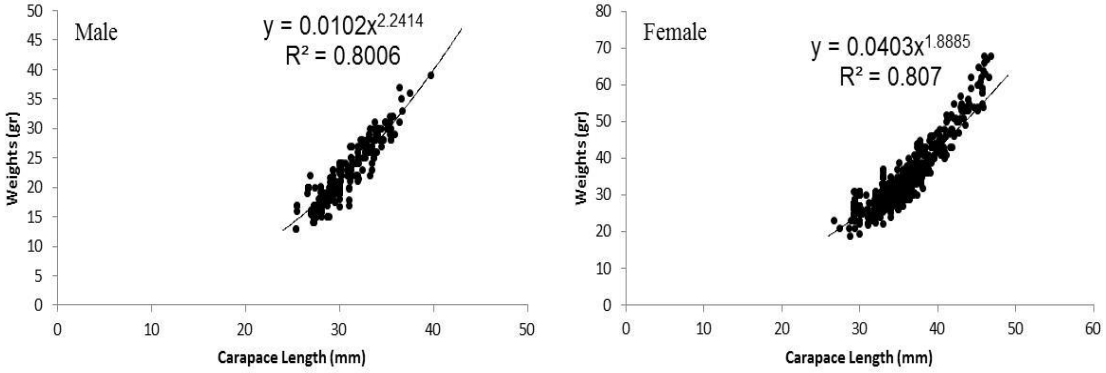

Figure 4. Length-weight relationship of males and females *Penaeus merguiensis* in Kaimana waters.

Length at first capture (Lc) and length at first maturity (Lm). The length at first capture (Lc) of *P. merguiensis* by trammel net in Kaimana waters was 33.4 mm (Figure 5). It was higher than the length at first capture of *P. merguiensis* in some areas such as Sampit (30.05 mm) and Tarakan waters (32.5 mm) (Nurdin & Kembaren 2015; Chodrijah & Suman 2017). The length at first captured of *P. merguiensis* in Kaimana (Lc = 33.4 mmCL) was smaller than the length at first maturity (Lm = 35.4 mmCL) so most of shrimps captured by trammel net were still immature or haven't spawned yet. The regulation related on the mesh size and minimum legal size could be the effective

management to maintain the sustainability of shrimp stock. The minimum legal size that was suggested from this research was 35 mm or less than 30 shrimps in 1 kg.

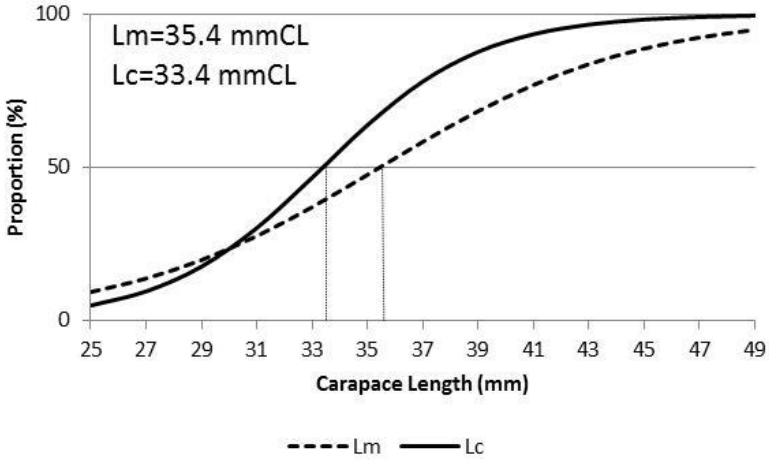

Figure 5. Length at first capture (Lc) and lengh at first maturity (Lm) of *Penaeus merguiensis* in Kaimana waters, 2017.

Growth. The asymptotic legth (L_∞) of *P. merguiensis* (*P. merguiensis*) in Kaimana waters was 44.7 mmCL for male and 51.25 mmCL for female. The asymptotic length in some locations ranged between 40.7-57.8 mmCL (Table 1). The asymptotic length of 40.7 mm was found in Cilacap and 57.8 mm in Sampit (Suman & Prisantoso 2017; Nurdin & Kembaren 2015). The asymptotic length of *P. merguiensis* in Kaimana now in 2017 was higher than the asymptotic length in Cenderawasih gulf, Papua in 2013. This condition was caused by the present low fishing pressure in Papua where the trawl gear was not operated since 2015.

Table 1
Asymptotic length (L_∞), growth rate (K) and exploitation rate (E) of *Penaeus merguiensis* in some areas

Location	*Sexes*	*L∞ (year-1)*	*K (year-1)*	E	*Source*
Cilacap, Central Java	Male	40.7 mmCL	1	0.56	Suman & Prisantoso (2017)
	Female	54.2 mmCL	1.1	0.36	
Tarakan, North Kalimantan	Male	45.2 mmCL	1.55	0.76	Chodrijah & Suman (2017)
	Female	57.6 mmCL	1.33	0.76	
Sampit, Central Kalimantan	Combined	57.8 mmCL	1.45	0.66	Nurdin & Kembaren (2015)
Tanal Laut, South Kalimantan	Combined	55 mmCL	1.05	0.74	Suman et al (2017)
Teluk Cenderawasih, Papua	Male	44.5 mmCL	1.05	0.66	Kembaren & Ernawati (2015)
	Female	48.7 mmCL	1.15	0.55	
Kaimana, West Papua	Male	44.7 mmCL	1.38	0.49	Present research
	Female	51.25 mmCL	1.4	0.44	

The growth rate (K) of *P. merguiensis* was 1.4 $year^{-1}$ for males and 1.38 $year^{-1}$ for females. The Von Bertalanfy growth equation was $Lt = 44.7 (1 - e^{-1.4(t+0.2)})$ for males and $Lt = 51.25 (1 - e^{-1.38(t+0.19)})$ for females (Figure 6). The growth rate (K) of *P. merguiensis* was generally higher than one that was indicated the fast growth of species (Sparre & Venema 1992). The maximum length of 43 mm for males was reached in age of 2.1 years and the maximum length of 49 mm for females was reached in age of 2.2 years. The length at first maturity (Lm = 35.4 mm) of female shrimps was estimated at the age of 10-11 months.

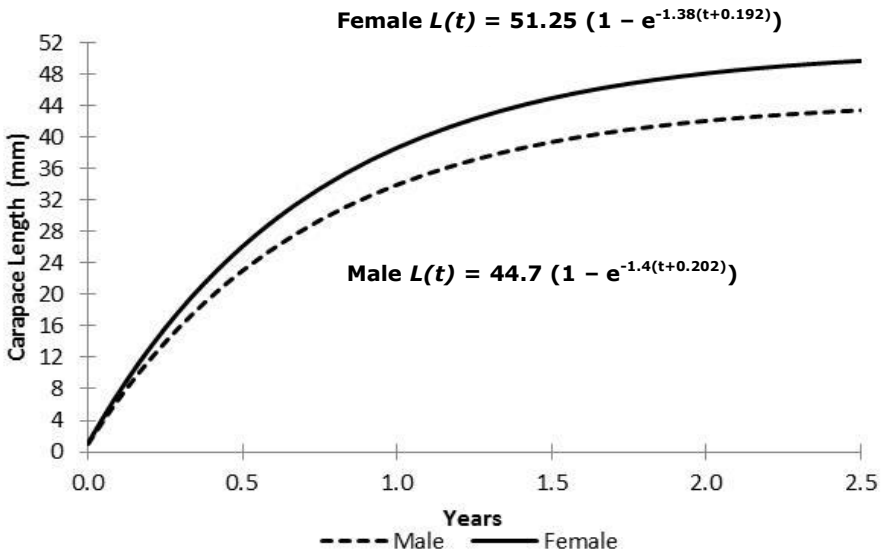

Figure 6. Von Bertalanffy growth curve of *Penaeus merguiensis* in Kaimana waters.

Mortality parameters and exploitation rate. Natural mortality (M) of *P. merguiensis* in Kaimana waters was 2.02 year^{-1} for males and 1.93 year^{-1} for females. Natural mortality (M) of *P. merguiensis* in Kaimana was higher than the natural mortality of *P. merguiensis* in Tanah Laut (M = 1.58 year^{-1}) and Cenderawasih gulf (M = 1.68-1.74 year^{-1}). Natural mortality was influenced by some factors such as the availability of food, disease, environment, competition and mainly factor the presence of predator species (King 1995; Sparre & Venema 1992; Niamaimandi et al 2007). The high natural mortality rate of *P. merguiensis* in Kaimana could be caused by the high density of demersal fishes as the main predator of shrimp. The potential biomass of demersal fishery in Arafura Sea was reported as 539.000 tons/year (Purwanto 2015). *Penaeid* shrimp was the prey of some demersal fishes such as humpback red snapper *Lutjanus gibbus*, fourfinger threadfin *Eleutheronema tetradactylum* and marine catfish *Arius* sp. (Bachok et al 2004; Titrawani et al 2013).

The exploitation rate of *P. merguiensis* in Kaimana was 0.49 for males and 0.44 for females (Table 2). The optimum exploitation rate suggested by Gulland (1983) was 0.5 so the exploitation rate of *P. merguiensis* in Kaimana waters was close to optimum value and it was still sustainable. The exploitation rate of *P. merguiensis* in some areas such as Tarakan, Tanah Laut and Cenderawasih gulf were higher than 0.5 so the exploitation level indicated overfishing (Chodrijah & Suman 2017; Suman et al 2017; Kembaren & Ernawati 2015). The changes of gears from trawl to trammel net since 2015 could influence the exploitation level of shrimps in Kaimana.

Table 2

Mortality parameters and exploitation rate of *Penaeus merguiensis* in Kaimana waters

Sexes	*Z* (*year*$^{-1}$)	*M* (*year*$^{-1}$)	*F* (*year*$^{-1}$)	*E*
Males	3.97	2.02	1.95	0.49
Females	3.44	1.93	1.51	0.44

Spawning potential ratio. Spawning potential ratio was determined by length based SPR with the input data of M/K ratio, asymptotic length (L_∞), length at first matured (Lm) and length at 95% proportion of matured females (Hordyk et al 2015). The spawning potential ratio of female *P. merguiensis* in Kaimana was determined to be 0.35 (Table 3).

Table 3
Mortality parameters and exploitation rate of *Penaeus merguiensis* in Kaimana waters

Parameters	*Values*
M/K ratio	1.40
L_∞	51.25
Lm_{50}	35.4
Lm_{95}	48.00
SPR	0.35

The spawning potential ratio was the ability of stock on the fishing pressure which is related to its reproduction that was determined as the comparison of the present of fishing mortality and the absence of fishing mortality (Goodyear 1993). The spawning potential ratio of some *Crustacean* in Indonesia such as mud crab (*Scylla serrate*) in Pati, blue swimming crab (*Portunus pelagicus*) in Belitung and *P. merguiensis* in Cenderawasih gulf was determined as less than 10% that indicated the high fishing pressure in that areas (Ernawati et al 2015; Ernawati et al 2016; Kembaren & Ernawati 2015). The threshold of spawning potential ratio for coral fish and shrimp was reported to be 20% (Prince et al 2015; NEFSC 1996). The spawning potential ratio for *P. merguiensis* in Kaimana (35%) was higher than the minimum threshold of SPR (20%) so the exploitation status was still sustainable. From the results, it was concluded that the exploitation level of *P. merguiensis* was still sustainable so the fishing could be continued without reducing the efforts but most of shrimps that was caught by trammel net was still immature so the regulation of mesh size and minimum legal size is needed for the sustainability of shrimps fisheries in Kaimana.

Conclusions. The catch rate of *P. merguiensis* by trammel net was quite high (11.6 kg/trip) and the exploitation status was still sustainable because the trawl was not operated since 2015 so the trammel net was the only gear for catching shrimps in Kaimana waters. The catch was dominated by the immature individuals so the management needs the regulation for minimum legal size. The results concluded that the *P. merguiensis* fishing could be continued without reducing the fishing effort with the regulation of just operating the trammel net for shrimp fishing and it is recommended to use minimum legal size of 35 mmCL or less than 30 shrimps in 1 kg.

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