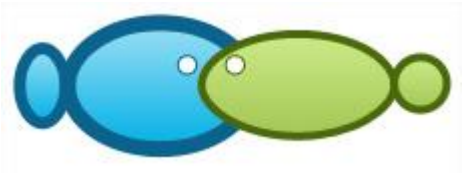

Fishery, population parameters and exploitation status of blue swimming crab (*Portunus pelagicus*) in Kwandang Waters, Indonesia

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Abstract. The high fishing pressure of blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) in some areas in Indonesia caused the decreasing of its stocks. The information about its exploitation in Kwandang Waters has not been reported yet so the stock assessment was needed as basis sustainable management for its resources. The aim of this research was to study the fishery, population parameters and exploitation status of *P. pelagicus* in Kwandang Waters. The catch landing data originated from 2,902 trips of gillnet, collected from January to December 2018 and the biometric data was obtained from 2,958 crabs, collected from June to December 2018 from the catch of fishers in Kwandang. The Von Bertalanffy Growth model was used for estimating growth parameters. Beverton and Holt's Yield per Recruit and Length Based-SPR were used for estimating exploitation status. The results showed that gillnet was a selective gear for catching *P. pelagicus* by its size and the annual mean catch rate was 4.79 kg trip^{-1} of which peak occurred in June and July. The size of *P. pelagicus* ranged between 70 to 175 mmCW. The asymptotic length was 174 mm for males and 180 mm for females. The growth rate (K) was 1.24 year^{-1} for males and 0.96 year^{-1} for females. The exploitation status showed no overfishing, based on the current fishing mortality (F_{2018}) which was less than the reference point $F_{0.1}$ and based on the estimated SPR of 24% so the fishing effort could continue and the minimum legal size of 117 mmCW could be implemented for the future management strategy.
Key Words: stock assessment, catch rate, gillnet, yield per recruit, minimum legal size.

Introduction. Blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) was one of the important Crustacean commodities which have high protein and a good taste so it caused high demand on its resources. The high demand on *P. pelagicus* caused the high economic values and the high exploitation of its resources. One of the fishing grounds for *P. pelagicus* in Indonesia was in Kwandang waters which were part of Fisheries Management Area (FMA) 716.

The government of Indonesia has divided the waters into 11 Fisheries Management Areas (FMA). The stock assessment of *P. pelagicus* has been reported in some FMA in Indonesia. The exploitation status of *P. pelagicus* in Kotabaru waters and Bone waters which was part of FMA 713 was on the overfishing stage (Tirtadanu & Suman 2017; Kembaren et al 2012). Ernawati et al (2015a) reported that the exploitation status of *P. pelagicus* in Belitung waters which was part of FMA 711 was categorized as heavily exploited. The condition of overfishing stage was also found in Jakarta Bay and Pati waters which was part of FMA 712 (Panggabean et al 2018; Ernawati et al 2015b). The high fishing pressure of *P. pelagicus* without sustainable management strategy caused the decrease of its stock in Thailand waters (Kunsook et al 2014). The specific study about exploitation status of *P. pelagicus* in Kwandang waters (part of FMA 716) has not been reported yet so the stock assessment was needed for the basis sustainable management of *P. pelagicus* in Kwandang waters.

The study that was needed to develop the sustainable management of *P. pelagicus* was the stock assessment including the fishery, the population parameters and its exploitation status. The *P. pelagicus* fishery was related to production, effort and catch rate as indicator of stock abundance (Gulland 1983). Population parameters including

mean length at first capture (Lc), mean length at first maturity (Lm), growth and mortality rate were important parameters for knowing the selectivity of the gear and the life history of *P. pelagicus* (King 1995). Exploitation status was the basis information for knowing the sustainability of *P. pelagicus* fisheries in Kwandang waters. It was hoped that this study could help the managers to develop the future management strategy for sustainable *P. pelagicus* fisheries in Kwandang waters.

Material and Method

Description of the study sites. Data collection of the present study included catch data and biological data. Catch data was obtained from the total catch (in kg) for *P. pelagicus* which was caught by Gillnet during January-December 2018 in Kwandang waters. Biological data was obtained from the measurement of carapace width (CW) and weights and the observation of sexes and maturity stage during July-December 2018.

The fishing ground of *P. pelagicus* was in the northern coast of Kwandang that was 3-8 miles from the landing areas (Figure 1). *P. pelagicus* was caught by gillnet which has the mesh size of 4 inches. The size of headrope was 50 m for each piece of gillnet and the height of gillnet was 1.5 m. The size of vessel was 2-4 GT and it used 5 pieces of gillnet for each vessel. The gillnet was operated by 1-2 fishers for each vessel and it was operated by one day fishing.

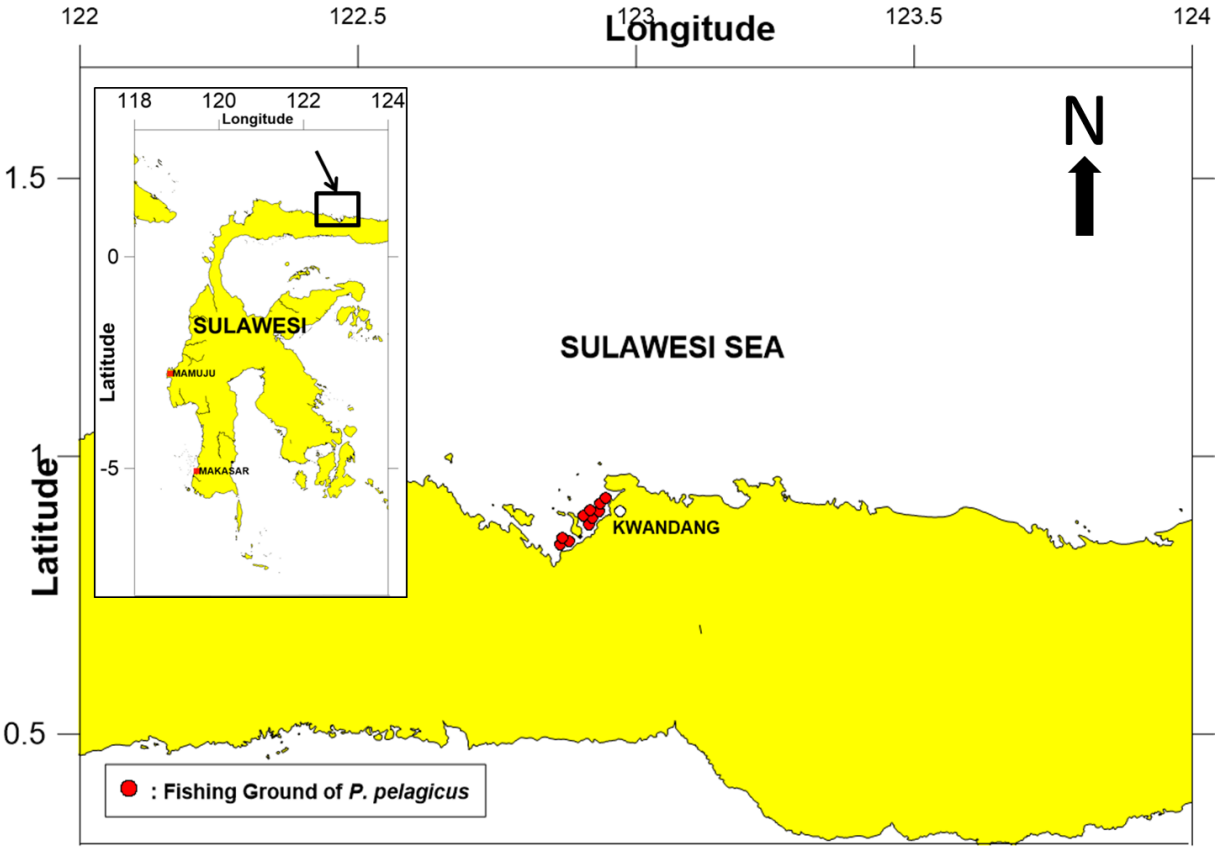

Figure 1. Fishing ground of blue swimming crab (*Portunus pelagicus*) in Kwandang waters.

Data analysis. The data analysis of the present study was grouped by fishery parameter, population parameter and exploitation status. Fishery parameters included total catch, total trips and catch rate of *P. pelagicus* by gillnet. Population parameters were: length-weight relationship, growth, the mean length at first captured (Lc) and the mean length at first maturity (Lm). Exploitation status included exploitation rate (E), Yield per recruit (Y/R) and Spawning Potential Ratio (SPR).

The length-weight relationship was calculated with the equation (King 1995):

$$W=aL^b$$

Where: W=weights (gram); L=Carapace Width (mm); a and b=regression constant.

The mean length at first captured (Lc) was estimated based on the logistic curve by the equation (Sparre & Venema 1992):

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

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

The immature group of *P. pelagicus* was including the gonadal maturity stage (GMS) I and GMS II. The mature group of *P. pelagicus* was including GMS III, GMS IV and berried. Mean length at first maturity was estimated based on logistic curve by the equation (King 1995):

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

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

The growth parameters including carapace width asymptotic (L_∞) and growth rate (K) was estimated by the movement of carapace width using Electronic Length Frequency Analysis/ELEFAN I in FISAT II packeges (Gayanilo et al 2005). The interval of 5 mm was used for the length distribution in hystogram chart. The growth parameter was based on the von Bertalanffy Growth model (Sparre & Venema 1992):

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

Where: L_t is the carapace width at age t; L_∞ is the asymptotic carapace width (mm); K is the growth rate and t_0 (t-zero) is the point in time when the blue swimming crab has zero carapace width.

The point in time when the crab has zero carapace width (t_0) was estimated by the equation of Pauly (1983):

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

Natural mortality was calculated by the equation of Pauly et al (1984) with the sea temperature of 29°C:

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

Total mortality (Z) was estimated from the linearized length-converted catch curve equation (Sparre & Venema 1992):

$$ln\frac{C(L1,L2)}{\Delta t(L1,L2)} = C - Z*t(\frac{L1+L2}{2})$$

Where: Z is total mortality; C is the frequency of the carapace width class; Δt is the time it takes for an average crabs to grow from L1 to L2; L1 is the carapace width at age t; L2 is the carapace width at age t+Δt.

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

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

Yield per Recruit was analyzed by Beverton and Holt model following the equation Beverton & Holt (1957):

$$\frac{Y}{R} = F*A*W_\infty*\left(\frac{1}{Z}-\frac{3U}{Z+K}+\frac{3U^2}{Z+2K}+\frac{U^3}{Z+3K}\right)$$

Where: F is Fishing mortality; W_∞ is asymptotic weight; Z is total mortality; K is growth rate; A is obtained from the equation $A=\left[\frac{L_\infty-L_c}{L_\infty-L_r}\right]^{M/K}$ and U was obtained from the equation $U=1-\frac{L_c}{L_\infty}$. The Biomass per Recruit was analyze by the equation of Sparre & Venema (1992):

$$\frac{B}{R} = \frac{Y}{R}*\frac{1}{F}$$

The reference point of fishing mortality ($F_{0.1}$) was obtained from Gulland & Boerema (1973) that it was the fishing mortality when the Yield per Recruit was equal to 10% of virgin biomass following the equation $V=Y-0.1*B_0*F$ where Y is Yield per Recruit Maximum (Y/R_{max}); F as independent variable and V as dependent variable (Cadima 2003).

The spawning potential ratio (SPR) was estimated by Length based SPR model (Hordyk et al 2015a,b). 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. Total samples of trips for gillnets vessels in 2018 were 2.902 trips and the total catch of *P. pelagicus* was 17,087 kg from the total vessel samples of 47 vessels. The monthly total samples of trips ranged between 70 to 324 trips and the monthly total catch was between 627 and 2,286 kg. The highest total catch was found in July and the highest total trips were found in July and October (Table 1).

Table 1

Total trips and total catch *Portunus pelagicus* by gillnets in Kwandang waters, 2018

Months	*Trips*	*Total catch (kg)*	*Mean CPUE*
Jan	217	868	3.94
Feb	209	889	4.25
Mar	241	990	4.11
Apr	220	1,209	5.50
May	277	1,385	4.98
Jun	178	1,290	6.98
July	314	2,286	6.93
Aug	313	1,795	5.10
Sep	70	627	3.63
Oct	324	1,930	3.85
Nov	311	2,157	4.06
Des	228	1,662	3.54
Total (2018)	2,902	17,087	4.79

The monthly mean catch per unit effort (CPUE) for *P. pelagicus* in Kwandang waters ranged between 3.54 and 6.98 kg $trip^{-1}$. The mean catch per unit effort (CPUE) of *P. pelagicus* by gillnet in 2018 was 4.79 kg $trip^{-1}$. The highest catch rate of *P. pelagicus* occurred in June and July (Figure 2). The peak of fishing season of *P. pelagicus* in Kwandang waters was similar to the fishing season in Jakarta Bay that was occurred in June and July (Nuraini et al 2009). Most of the fishing season peak of *P. pelagicus* in some areas in Indonesia occurred in June and July which was a dry season in Indonesia. The peak of fishing season of *P. pelagicus* in Pangkep occurred in June and the peak of fishing season of *P. pelagicus* in Tangerang occurred in July (Ihsan et al 2014; Prihatiningsih & Wagiyo 2009).

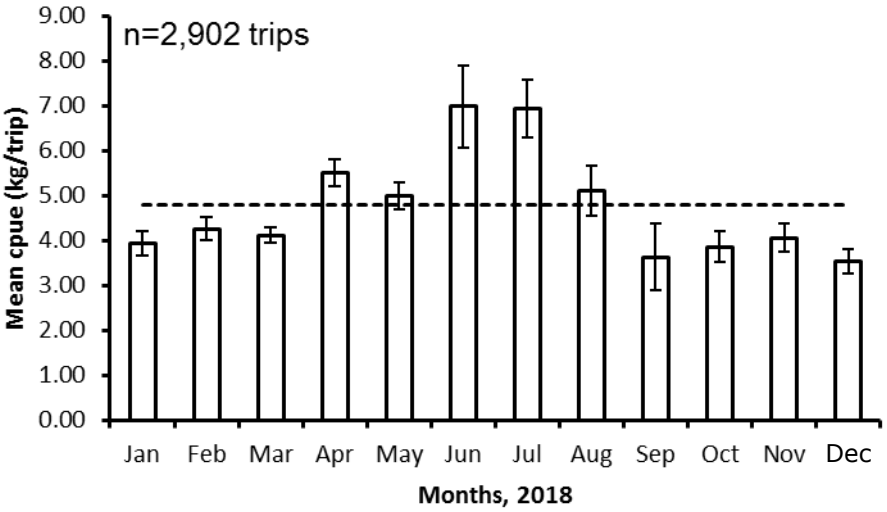

Figure 2. Monthly mean CPUE of gillnet for *Portunus pelagicus* in Kwandang waters, 2018.

Carapace width distribution and growth. Total samples of *P. pelagicus* that was measured for the carapace width was 1,528 male and 1,430 female individualss. The carapace width of *P. pelagicus* ranged between 70 and 170 mm for males and 70 to 175 mm for females (Figure 3). The mean length of *P. pelagicus* was 125±0.45 mm for males and 126±0.45 mm for females. The size of *P. pelagicus* in Kwandang waters was larger than the size of *P. pelagicus* in Jakarta Bay and Bone waters. The carapace width of *P. pelagicus* in Jakarta Bay ranged from 60 to 145 mm for males and 60 to 150 mm for females (Panggabean et al 2018). The carapace width of *P. pelagicus* in Bone waters ranged from 32.5 to 147.5 mm (Kembaren et al 2012). The different size of *P. pelagicus* in some areas can be caused by the different selectivity of the gear and the different fishing pressure of its resources.

The asymptotic carapace width (L_∞) of *P. pelagicus* in Kwandang waters was 174 mm for male and 180 mm for female individuals. The growth rate (K) was 1.24 year^{-1} for males and 0.96 year^{-1} for females. The Von Bertalanffy growth equation of *P. pelagicus* in Kwandang waters was $L_t=174(1-e^{-1.24(t+0.12)})$ for males and $L_t=180(1-e^{-0.96(t+0.09)})$ for females (Figure 3). The asymptotic carapace width of *P. pelagicus* in some areas ranged between 142.6 and 187 mm. The growth rate (K) ranged between 0.96 to 2.75 year^{-1} (Table 2). The maximum age of *P. pelagicus* in Kwandang waters was estimated at the age of 2.4 years for males and 3 years for females. Sukumaran & Neelakantan (1997) reported that the lifespan of *P. pelagicus* was around 2.5 years. Johnston et al (2011) noted that *P. pelagicus* could reach the age of 3 to 4 years in the unexploited condition.

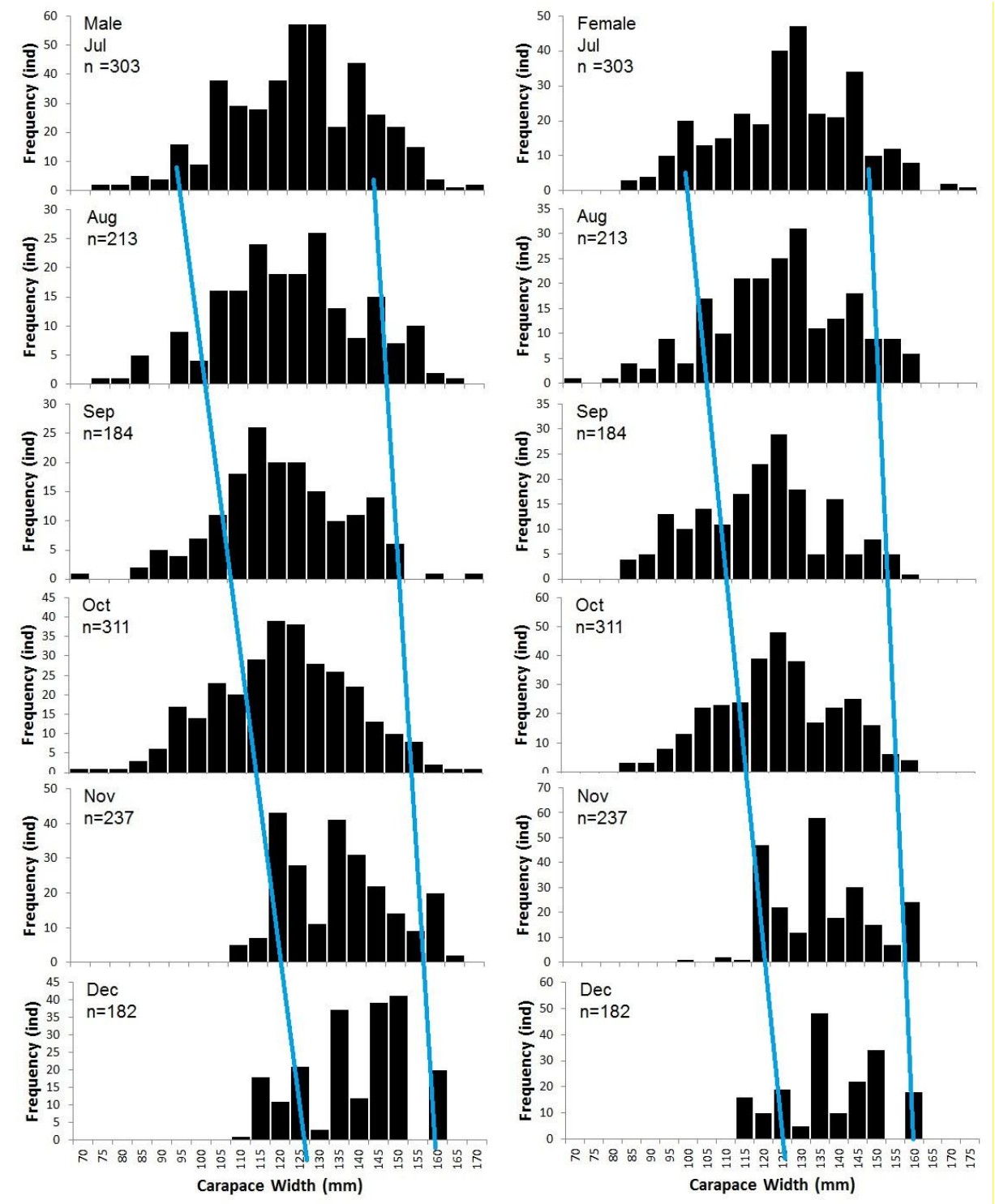

Figure 3. Length frequency and Von Bertalanffy growth curve of *Portunus pelagicus* in Kwandang waters, 2018.

Table 2

Asymptotic carapace width (L_∞), growth rate (K) and exploitation status (E) of *Portunus pelagicus* in some areas

Location	*Sexes*	L_∞ *(mmCW)*	*K* $(year^{-1})$	*E*	*References*
Pakistani waters, Pakistan	Combined	178.5	1.7	0.66	Afzaal et al (2016)
Bandar Abbas waters, Persia	Combined	172.5	0.98	0.51	Kamrani et al (2010)
Kung Krabean Bay, Thailand	Male	142.6	2.75	0.55	Kunsook et al (2014)
	Female	167.3	1.13	0.7	
Jakarta Bay, Indonesia	Combined	157	1	0.49	Panggabean et al (2018)
Pati Waters, Indoensia	Male	185	1.26	0.8	Ernawati et al (2015b)
	Female	187	1.13	0.81	
Bone Bay, Indonesia	Male	159	1.27	0.82	Kembaren et al (2012)
	Female	154	1.08	0.78	
Kotabaru waters, Indonesia	Male	179.2	1.36	0.68	Tirtadanu & Suman (2017)
	Female	183.6	1.11	0.77	
Kwandang waters, Indonesia	Male	174	1.24	0.36	Present study
	Female	180	0.96	0.44	

Length-weight relationship. The length-weight relationship of *P. pelagicus* in Kwandang waters followed the equation $W=0{,}00006*L^{3{,}0196}$ for males and $W=0{,}00005*L^{3{,}0471}$ for females (Table 3). The value of b was equal to 3 that showed an isometric pattern. This condition showed that the growth of length was equal to the growth of weights. The growth pattern of *P. pelagicus* in Sulawesi waters was negative allometric for both male and female specimens (Sara et al 2016). The growth pattern of *P. pelagicus* in Lampung waters was isometric for males and positive allometric for females (Damora & Nurdin 2016). The growth pattern of *P. pelagicus* in Mandapam Coast, India was allometric for males and isometric for females (Josileen 2011).

Table 3

Length-weight relationship of *Portunus pelagicus* in Kwandang waters, 2018

Sexes	*N*	*a*	*B*	R^2	*Growth pattern*
Male	208	0.00006	3.0196	0.9112	Isometric
Female	244	0.00005	3.0471	0.9267	Isometric
Combined	452	0.00005	3.0389	0.9238	Isometric

Mean length at first capture (Lc) and mean length at first maturity (Lm). The mean length at first capture (Lc) of *P. pelagicus* by gillnet in Kwandang waters was 121 mm CW. The mean length at first maturity of female *P. pelagicus* was 117 mm CW (Figure 4). The age of *P. pelagicus* to reach its mean length at first capture was 14 months and the age of *P. pelagicus* to reach its mean length at first maturity was 13 months. The age at first maturity in the present study (t_m=13 months) was close to the age at first maturity reported by Potter & de Lestang (2000) that was one year old.

Nuraini et al (2009) found that gillnet in Jakarta Bay was more selective for catching *P. pelagicus* than mini trawl, lift net and barrier trap. The mean length at first capture of *P. pelagicus* in Kwandang waters (Lc=121 mmCW) was higher than the mean length at first maturity (Lm=117 mmCW) which indicated that most of *P. pelagicus* has spawned at least once before they were captured so the recruitment could occur. It showed that the gillnet was a selective gear but a ban of *P. pelagicus* catching should be still implemented for sustainable *P. pelagicus* fishery in Kwandang waters.

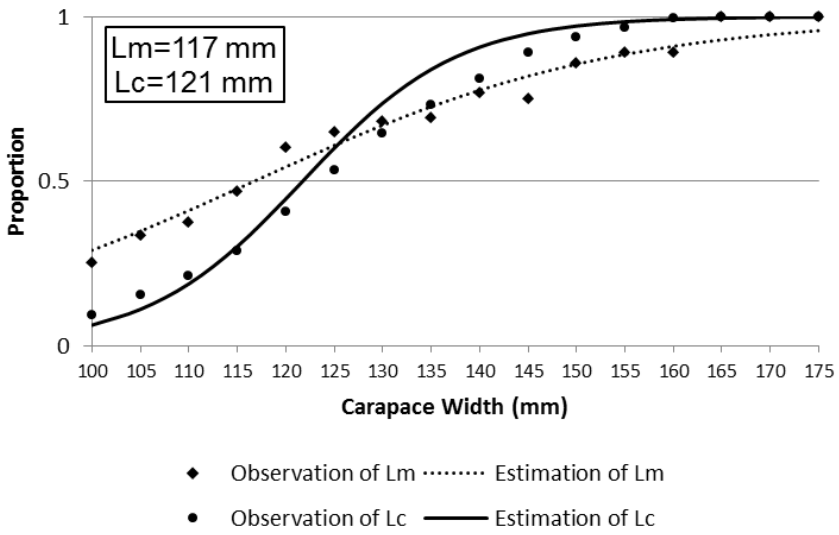

Figure 4. Mean length at first capture (Lc) and mean length at first maturity (Lm) *Portunus pelagicus* in Kwandang waters, 2018.

Exploitation rate. The natural mortality of *P. pelagicus* in Kwandang waters was 2 year^{-1} for males and 1.93 year^{-1} for females. The fishing mortality of *P. pelagicus* in Kwandang waters was 0.72 year^{-1} for males and 0.86 year^{-1} for females. The exploitation rate of *P. pelagicus* in Kwandang waters was 0.36 for males and 0.44 for females (Figure 5). The exploitation rate of *P. pelagicus* in some areas in Indonesia was between 0.36 and 0.82 (Table 2). Gulland (1983) noted that the optimum exploitation rate was 0.5. The exploitation rate (E) of *P. pelagicus* was less than 0.5 so the exploitation status of *P. pelagicus* in Kwandang waters was still sustainable.

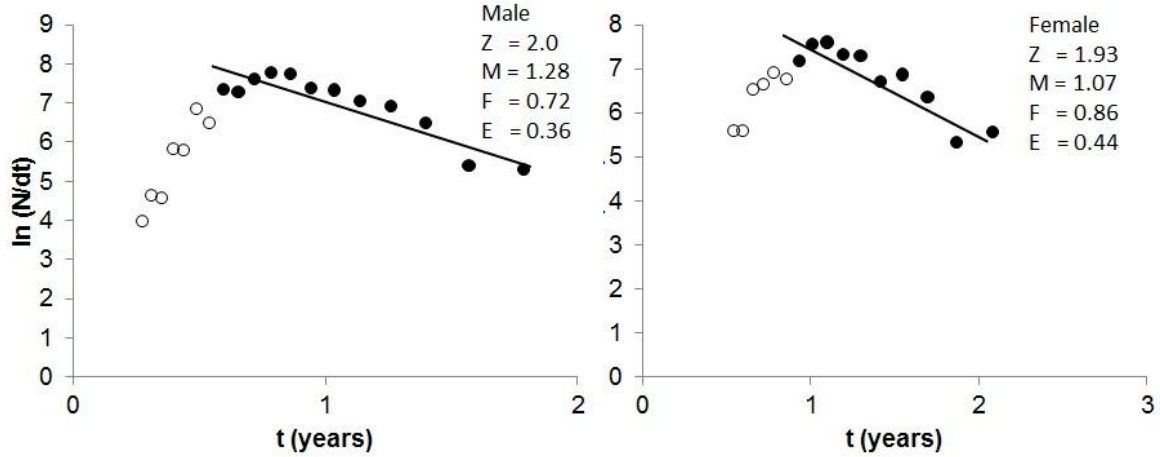

Figure 5. Length converted catch-curve of *Portunus pelagicus* in Kwandang waters.

Yield per recruit. The current yield per recruit was estimated as 44.7 g recruit^{-1} at the current fishing mortality of 0.86 year^{-1} (Table 4). It was showed that a recruitment of 100,000 crabs gives a yield of 4.47 tons (Sparre & Venema 1992). The current biomass per recruit was at 52 g recruit^{-1} or 5.58% from the virgin biomass that was higher than the maximum sustainable biomass per recruit (6.25 g recruit^{-1}) and the reference point of biomass per recruit (21.6 g recruit^{-1}). It showed that the current biomass of the survival stock is still higher than the reference point of biomass per recruit.

The yield per recruit of *P. pelagicus* in Kwandang waters increased when the fishing effort was increased until the fishing mortality at the values of 10.2 year^{-1} (Figure 6). The yield per recruit of *P. pelagicus* in Kwandang waters was decrease after the fishing effort reach the values of >F_{max} or >10.2 year^{-1}. The current fishing mortality

(F_{cur}=0.86) was still less than the maximum sustainable fishing mortality (F_{max}=10.2) and the reference point of the fishing mortality ($F_{0.1}$=2.8) so the exploitation status of *P. pelagicus* in Kwandang waters was not included in the overfishing status, which means we are talking about a sustainable status.

Table 4

Fishing mortality and reference point of *Portunus pelagicus* in Kwandang waters, 2018

Parameter	F_{cur}	F_{max}	$F_{0,1}$
F (year^{-1})	0.86	10.2	2.8
Y/R (gr/r)	44.7	63.7	60.6
B/R (gr/r)	52.0	6.25	21.6

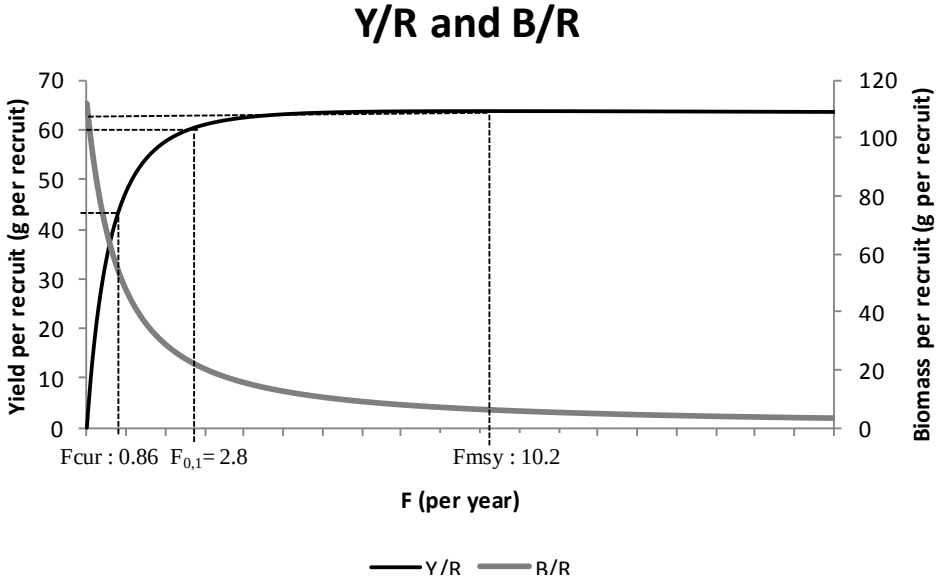

Figure 6. Yield per recruit and Biomass per recruit of *Portunus pelagicus* in Kwandang waters, 2018.

Spawning potential ratio. The spawning potential ratio was a measure of the impact of fishing on potential productivity of stock and it ranged between zero (resources fully depleted) and 100% (virgin resources or unexploited resources) (Goodyear 1993; Brooks et al 2010). The spawning potential ratio was estimated from the carapace width composition of female *P. pelagicus* catch and the life history such as asymptotic length (L_∞), the ratio of natural mortality to growth rate (M/K), the variability of length-at-age (CVLinf) and the size at maturity of Lm_{50} and Lm_{95} (Hordyk et al 2015b; Prince et al 2015). The spawning potential ratio of *P. pelagicus* in Kwandang waters was estimated as 24% (Table 5).

Table 5

Spawning potential ratio of *Portunus pelagicus* in Kwandang waters, 2018

Parameter	*Values*
L_∞	180 mm
M/K	1.1
Lm_{50}	117 mm
Lm_{95}	173 mm
SPR_{2018}	24%

The recruitment overfishing threshold SPR from some Crustaceans was 20% (Rosenberg et al 1994; Mace & Sissenwine 1993). The current spawning potential ratio of *P. pelagicus* in Kwandang waters was more than 20% so the *P. pelagicus* in Kwandang

waters was not in the stage of recruitment overfishing so the fishing effort of *P. pelagicus* could continue without reducing the effort. The minimum legal size of 117 mm as the length at first maturity of *P. pelagicus* could be implemented to reach the target reference point of 30%-40% SPR.

Conclusions. The gillnet used by fishers for catching *P. pelagicus* has the annual mean catch rate of 4.79 kg $trip^{-1}$ and the peak of catch rate was occurred in June and July. Gillnet was a selective gear based on the length at first capture (Lc=121 mmCW) which was less than the length at first maturity (Lm=127 mmCW). The length of *P. pelagicus* ranged between 70 and 170 mm for males and from 70 to 175 mm for females and the carapace width asymptotic was 174 mm for males and 180 mm for females. The growth rate (K) was 1.24 $year^{-1}$ for males and 0.96 $year^{-1}$ for females. The exploitation status of *P. pelagicus* in Kwandang was still sustainable based on the exploitation rate of 0.36 for male crabs and 0.44 for females; the current fishing mortality (F_{cur}=0.86) was less than the fishing mortality reference point ($F_{0.1}$=2.8); and the spawning potential ratio was of 24%. The fishing effort of *P. pelagicus* could continue and the minimum legal size of 117 mm is recommended for the sustainable management of *P. pelagicus* in Kwandang waters.

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