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Population Parameters and Exploitation Ratio of Blue Swimming Crab, *Portunus pelagicus* (Linnaeus, 1758) from the Bawasalo Waters Pangkep Regency, South Sulawesi

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ABSTRACT

A total of 1315 individuals were collected from the catches off the Bawasalo waters during March -August 2023. This study aimed to analyze the population parameters and exploitation rate of blue swimming crab (*Portunus pelagicus*), caught by fishermen using a bubu naga fishing gear in the waters of Bawasalo, Pangkep District, South Sulawesi. The observed parameters included the size distribution of the carapace width, carapace width-weights relationship, age group, growth rate, total mortality rate, natural rate, fishing rate, and exploitation ratio analyzed with the ELEFAN II program. The size of carapace width ranged from 6.70 to 13.80cm, with the highest proportion observed at carapace widths between 9.10 and 9.60cm (19.7%) and the lowest proportion observed at carapace widths between 13.3 and 13.8cm (0.2%). Carapace widths below 10cm accounted for 66.69% of captures, while those above 10cm accounted for 33.31%. The carapace width-weight relationship was computed as $W = 0.1038L^{2.7334}$ (negative allometric). The von Bertalanffy growth parameters were estimated to be $K = 0.41\ yr^{-1}$, Lmax = 15.10 cm, and t0 = -0.723 yr. The total mortality (Z), natural mortality (M), and fishing mortality (F) were calculated as 2.70, 1.22, and 1.48 yr^{-1}, respectively. The exploitation rate (E = 0.55) suggests that the stock of *P. pelagicus* was slightly higher than that of an optimally exploited stock.

INTRODUCTION

Blue swimming crab is widely distributed throughout Indonesia **(Kusuma dan Dewi, 2017)**. In several regions of Indonesia, blue swimming crab is used as one of the people's fishery businesses including the Pangkep Regency **(Ihsan *et al*., 2014; Nurdin *et al*., 2016)**, Lasongko Bay **(Hamid *et al*., 2015)** and the Thousand Islands **(Agus *et al*., 2016)**.

Pangkep Regency, located in south Sulawesi, has waters with considerable blue swimming crab (*P. pelagicus*) that has the potential to became one of the important commodities. In Pangkep Regency itself, one of the blue swimming crab producing centers is on Salemo Island **(Nurdin *et al*., 2016b)**. The total exports of blue swimming crab in 2020 reached 27,616,332 tons, with an export value reaching USD 367,519,713 **(KKP, 2021)**. It ranks fourth in the total export value of Indonesian fishery products after shrimp, tuna and squid / cuttlefish / octopus.

The high export value indicates high production activities and exploitation of blue swimming crab, supported by open access fishing activities. Blue swimming crab (*P. pelagicus*) is currently under considerable pressure as the volume and size of the catch decreases **(Wiyono, 2015)**. High fishing pressure from blue swimming crab (*P. pelagicus*) in some areas in Indonesia has led to a reduction in stocks **(Tirtadanu, 2019)**. The catch and abundance of blue swimming crab on Salemo Island, Pangkep Regency, has decreased affecting the income of fishermen **(Nurdin *et al.*, 2015)**. Fisheries resources have seriously declined due to overfishing, illegal fishing activities, and pollution **(Mehanna *et al*., 2018; Lin *et al*., 2019; Asiedu *et al*., 2023)**.

Biological information and population dynamics are radical for stock estimation **(Then *et al.*, 2018)**. Moreover, information regarding biological aspects is a major factor for management purposes **(Sujatha *et al.*, 2015)**. Therefore, for management purposes, information on fisheries biology and population structure is required **(El-Kasheif, 2021)**. The sustainability of the blue swimming crab requires population biology information and estimating fishery stocks as a scientific basis study for the availability of sustainable resources **(Froese *et al*, 2011; Maiyza *et al*., 2020**). Research related to blue swimming crab in Pangkep Regency has been made regarding the arrest **(Ihsan, 2018)**. Bawasalo waters is one of the blue swimming crab fishing areas in Pangkep Regency. However, studies on the population parameters and exploitation ratio of blue swimming crab (*P. pelagicus*) caught with bubu naga in Bawasalo waters have not yet been conducted. Based on this, it was important to conduct research related to population parameters and exploitation rates which included the distribution of carapace width, carapace width-weight relationship, age group, growth rate, mortality rate, and rate of exploitation. These atudies are crucial for assessing the sustainability of blue swimming crab resources.

MATERIALS AND METHODS

A total of 1159 blue swimming crabs (*P. pelagicus*) were randomly drawn from March 2023 to August 2023 from the catch of bubu naga originating from Bawasalo waters, Segeri District, Pangkep Regency (Fig. 1). Each sample of blue swimming crab was measured for carapace width (CW) in cm (The width of the blue swimming crab is measured from the longest lateral spines on the sides of its body) and weight (W) in g.

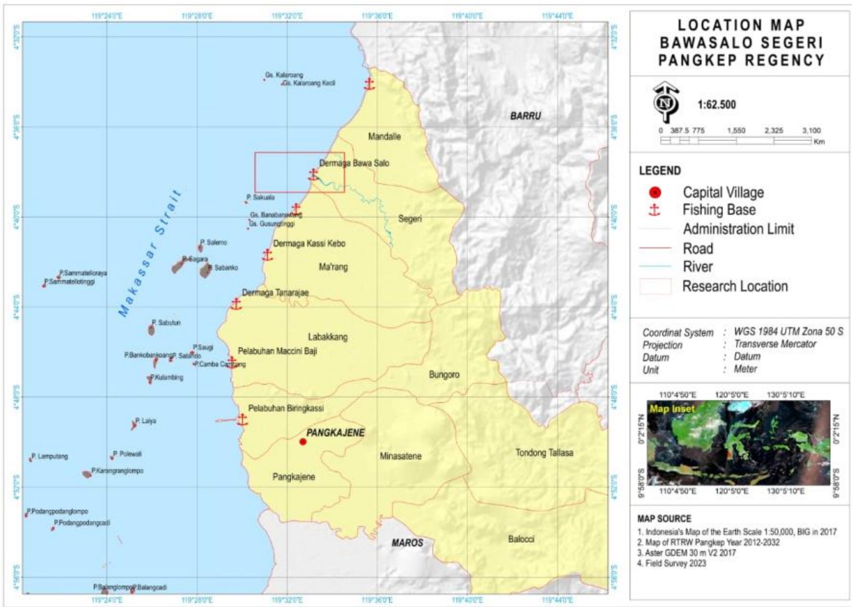

Fig. 1. Map of research location of *P. pelagicus* in Bawasalo waters

Length frequency data were analyzed by using the Bhattacharya's method **(Bhattacharya, 1967)** that was involved in the FiSAT II software package **(Gayanilo, 2005)**.

The total length and body weight of fish were used for the length-weight relationship. The length-weight relationship was analyzed using the equation below **(Ricker, 1975)**:

$$W = aL^b$$

Where, W = Total body weight of the fish (g); L = Total carapace width (cm); "a" = Regression constant, and "b" = Koefisien regresi; Value "b" provide information about the type of fish growth. The degree of association between length-weight variables was calculated by the correlation coefficient (R2), and the degree of its statistical significance was assessed following the method indicated by **Santos *et al*. (2002)**, as follows:

$$\text{Log } W = \text{Log } a + b \text{ Log } TL$$

If b = 3, the growth is isometric, b ≠ 3, the growth is allometric (allometric negative if b < 3, and the allometric is positive if b > 3).

Growth parameters followed the growth function of von Bertalanffy (VBGF) including growth rate (K) and asymptotic length (L∞) with equations.

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

Where, Lt is the average length at time (or age) t, L ∞ is the asymptotic mean length; K is the coefficient of growth rate (per year), and t; represents time or age. The theoretical age at zero length (t0) followed the equation shown by **Pauly (1979)**, as follows:

$$\text{Log } 10 (-t_0) = -0.3922 - 0.2752 \log 10\, L_\infty - 1.038 \log 10\, K$$

Estimation of total mortality (Z) was carried out by the length converted catch curve method **(Pauly, 1983)**. Natural mortality rate **(M) = Log M = -0.0066 – 0.279 log L∞ + 0.6543 log K + 0.4634 log T (Pauly, 1980)**, with a flat temperature of 30^0C. Fishing mortality rate (F)= Z-M. Exploitation rate was calculated using the equation described by **Gulland (1971)**: **E = F/Z**.

Long was allegedly first caught based on the cumulative probability of fishing effort across the middle of the width class. From the resulting curve, Long was first caught (Lc50), defined as the average total length where 50% of the fish are caught, taken according to the cumulative probability at 50%. This procedure follows the method described by **Beverton dan Holt (1956)** and **Sparre dan Venema (1998)**, as follows:

Lc50 = [TL – K(TL∞ – TL'')]/ Z

Where, Lc50 is the first length, and T times caught, where L 'is the average length of fish in the catch sample. Moreover, length at 75 and 95% fishing correlates with cumulative probability at 75 and 95%, respectively, as shown by **Pauly (1983)**.

The result per recruit (Y/ R) was determined according to the formula developed by **Beverton dan Holt (1957**), and the relative per recruit (Y / R0) was calculated according to **Pauly and Soriano (1986)**.

Data analysis

The FiSAT II tool was used to assess the population parameters, such asymptotic length (L∞), growth rate (K), natural mortality rate (M), fishing mortality rate (F), exploitation ratio (E), and relative yield per recruit indicators of samples from the assessed fish species encountered during the study period **(Gayanilo *et al*., 2005)**.

RESULTS

Carapace width distribution

During the study period from March 2023 to August 2023, a total of 1315 individuals of blue swimming crab (*P. pelagicus*) were caught with bubu naga in Bawasalo waters, Pangkep Regency. The carapace width distribution ranged from 6.70 to 13.80cm, with the highest proportion observed at carapace width, 9.10 to 9.60cm (19.7%), and the lowest proportion observed at carapace width, 13.3 to 13.8cm (0.2%) (Fig. 2).

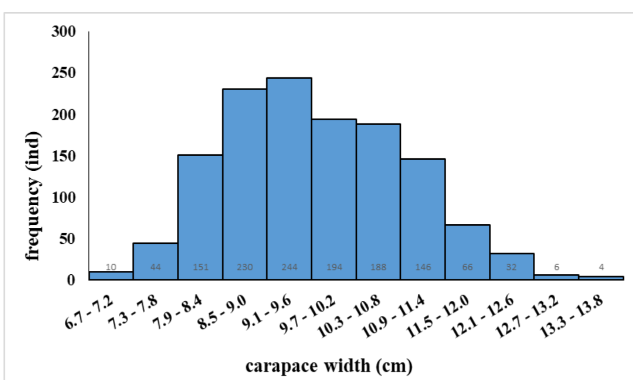

Fig. 2. Carapace width distribution of blue swimming crabs (*P. pelagicus*) in Bawasalo waters

Carapace width-weight relationship

The carapace width and weight relationship for males, females and combined sexes of *P. pelagicus* was described in the following equation as : W= $0.1052L^{2.7245}$ (R2 = 7478) (Fig. 3).

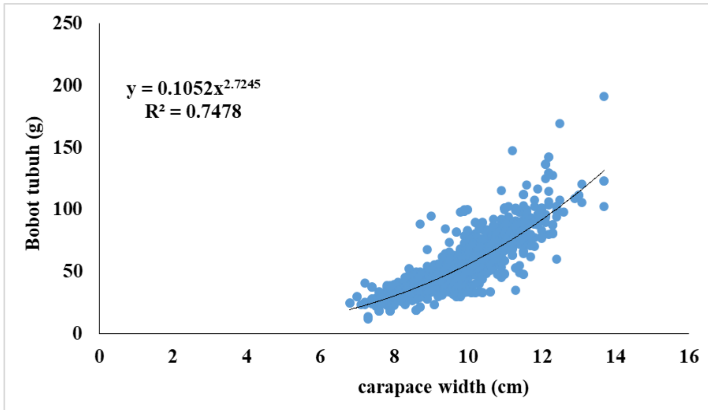

Fig. 3. Width-weight relationship of blue swimming crab (*P. pelagicus*) in Bawasalo waters

Age group

A cohort analysis using Battacahrya's method for *P. pelagicus* consists of three age groups, as shown in Fig. (4). Three cohort groups were identified with lengths of 8.66± 0.67, 10.27± 0.93, and 12.16± 0.21cm.

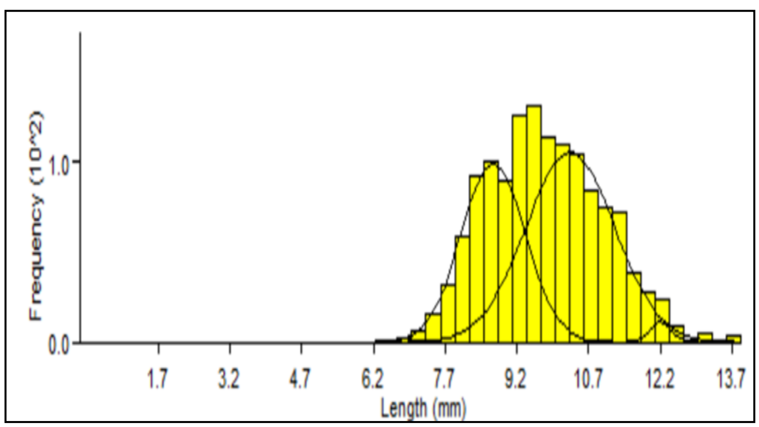

Fig. 4. Cohort groups using Bhattacharya's method in Bawasalo waters

Growth parameters

The estimated values of growth parameters were analyzed using the FISAT II program. The results of the analysis of the growth parameters estimation using the von

Bertalanffy formula for the blue swimming crab *P. pelagicus* included a maximum length (L∞) of 15.1cm, growth coefficient (K) of 0.41 per month, and age at birth (t0) of -0.48 (Fig. 5).

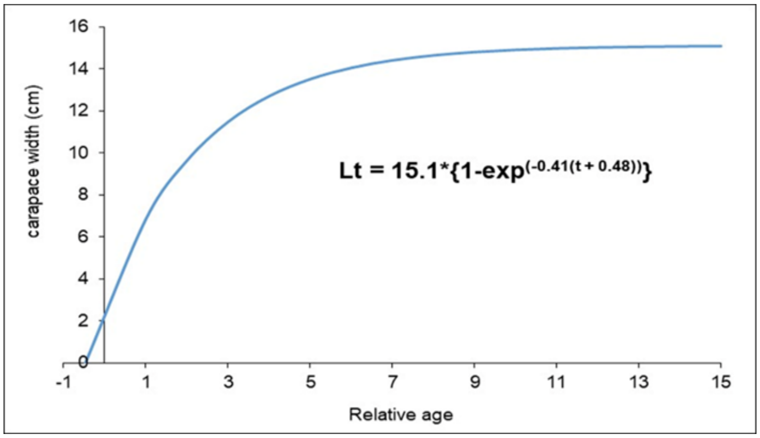

Fig. 5. Growth curve using von Bertalanffy blue swimming crab (*P. pelagicus*) in Bawasalo waters

Moralities and exploitation ratio

Mortality analysis based on the length-converted catch curve (Fig. 6) yielded the total mortality rate, natural mortality, fishing mortality, and exploitation ratio of the blue swimming crab (*P. pelagicus*).

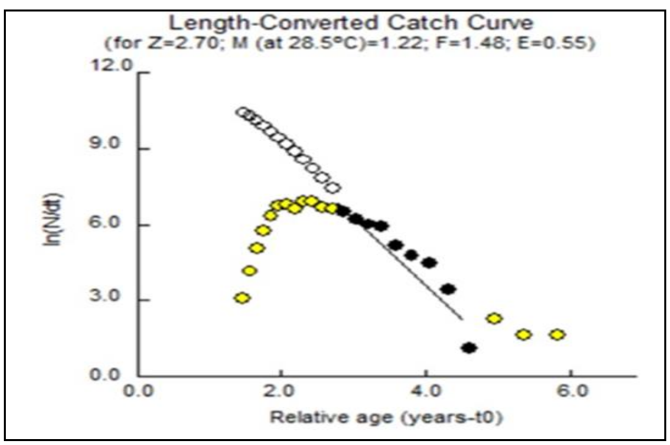

Fig. 6. Growth curve using von Bertalanffy blue swimming crabs (*P. pelagicus*) in Bawasalo waters

The total mortality (Z) was 2.70 yr^{-1}, natural mortality (M) and fishing mortality (F) were 1.22 and 1.48 yr^{-1}, respectively, and the exploitation ratio was 0.55 (Table 1).

Table 1. Value of population paramters blue swimming crab (*P. pelagicus*) in Bawasalo waters

Parameters	Value
Total mortality (Z)	2.70 yr-1
Natural mortality (M)	1.22 yr-1
Fishing mortality (F)	1.48 yr-1
Length at first capture (Lc)	8.56 cm
Length of recruitment (Lr)	8.22
Age at first capture (tc)	1.56
Age of recruitment (tr)	1.43
Exploitation ratio (E cur.)	0.55
The yield per recruit (Y/R)	20.6g
Biomass per recruit (B/R)	12.3g
The relative yield per recruit (Y/R')	0.009
Lc/L∞	0.567
M/K	2.976

Length at first capture

The length at first capture (Lc50) was 10.92cm. The length of catch probability at 25% (Lc25) and 75% (Lc75) was 10.53 and 11.22cm, respectively (Fig. 7).

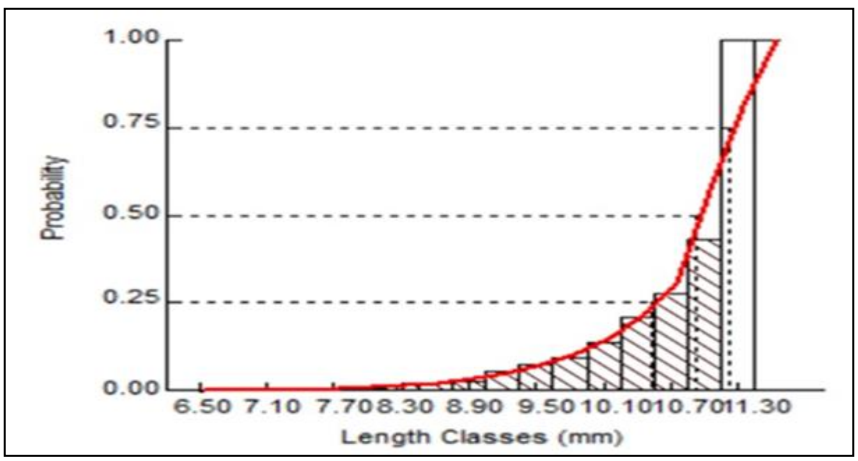

Fig. 7. Probability of capture

Yield per recruit (Y/R) and relative yield per recruit (Y’/R)

The yield per recruit (Y/R) for *P. pelagicus* was 20.6g at the current level of mortality (F cur) of 4.8 yr^{-1} (Fig 8). The relative yield per recruit (Y'/R) for different exploitation ratios is shown in Fig. (9). From this curve, the maximum Y'/R is found at the exploitation ratio (Emax) of 0.50. An exploitation ratio (E) of 0.3 would result in the maximum Y/R', protecting about 50% of the stock biomass.

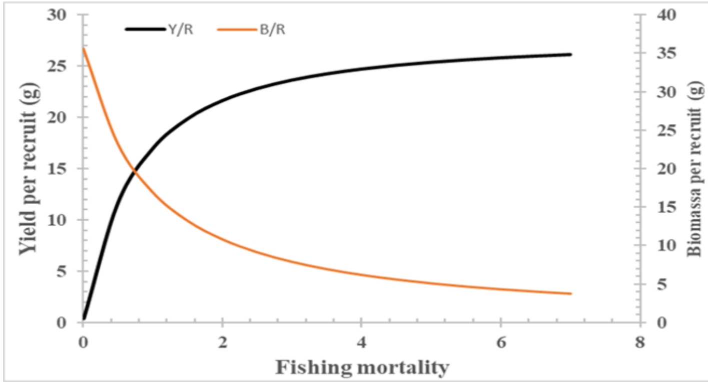

Fig. 8. Yield per recruit, biomass per recruit of blue swimming crab (*P. pelagicus*) in Bawasalo waters

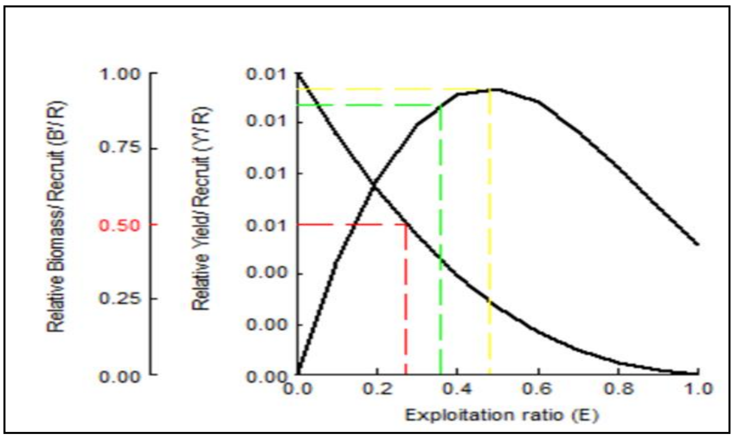

Fig. 9. Relative yield per recruit and relative biomass per recruit in relation to different exploitation ratio of *P. pelagicus* in Bawasalo waters

DISCUSSION

Carapace width distribution of blue swimming crab (*P. pelagicus*) during the study ranged between 6,70– 13,80cm. Approximately, 66.69% of the crabs had a carapace width of less than 10cm, while 33.31% had a carapace width greater than 10cm. In the research conducted by **Ihsan (2018)** in Pangkep waters, the dominant class interval for male blue swimming crabs was found to be 112- 123mm, with a frequency of 265 individuals (31.77%). For female blue swimming crabs, the dominant class interval was 100- 111mm, with a frequency of 223 individuals (26.74%). The research results of **Abdul Hamid (2019)** in Lasongko Bay show that the carapace width of male blue swimming crab ranges from 4.1- 12.4cm. The size of *P. pelagicus* obtained in Kwandang waters ranges from 7.0– 17.5cm **(Tirtadanu *et al*., 2019)**. The catches of blue swimming crabs obtained in Gresik and Lamongan are dominated by individuals with a carapace width size class of 11- 12cm and a weight of 70- 90g. The carapace width distribution shows that the carapace width capture >10cm account for 94% **(Rahman *et al.*, 2019**). In the coastal waters of the northern Persian Gulf, Iran, crab populations are dominated by adult crabs (carapace width >100mm) from December to May, while juvenile crabs are dominant from June to October **(Safaie *et al*., 2015)**. The width of the crab carapace fluctuates from 60- 150mm (males) and 50- 145mm (females). The total weight of males ranges from 48.0- 275.50g, and for females from 39.50 to 255.20g **(Hosseini *et al*., 2012)**. The length-weight relationship is one of the most important biological characters of fish, where weight of the fish increases as a function of its length **(Abeer *et al.*, 2022)**. In Fig. (3), the exponent value (b) is different from 3, indicating that the increase in carapace width is not as fast as the increase in weight. The coefficient b of 2.7344 indicates a negative allometric growth (P< 0,05).

The same research findings were obtained by **Muhsoni *et al.* (2009)** in Bangkalan-Madura waters; for both males and females b< 3. The same results were also obtained in the study by **Kanedi (2020)** in the East Lampung waters. However, these results differ from those of **Ningrum (2015)**, who showed a value of b> 3 (positive allometric) in the waters of Betahwalang and also at TPI Bulu, Jepara, indicating a positive allometric growth pattern **(Iksanti, 2022)**. Carapace width-total weight relationship showed a positive allometric growth (b-value= 3.10) **(El-Kasheif, 2021)**. **Afzaal (2018)** reported that, the carapace length-weight relationships for separate sexes (male and female) of *P. pelagicus* were calculated as $W = 0.967L^{2.91}$ ($R^2 = 0.874$), and the carapace width-weight relationships were calculated as $W = 0.8138L^{2.95}$ ($R^2 = 0.882$). Blue swimming crab male and female crabs found in Bone waters consists of 1- 3 cohorts (**Kembaren *et al*., 2012**). The existence of cohort differences is suspected to be indicative of subpopulation changes resulting from fishing pressure, with the fishing pressure on the subpopulation decreasing (**Ernaningsih *et al*., 2022**).

The value of the growth parameter von Bertalanffy predicts the relationship between fish stock estimation and fisheries resource management **(Abeer *et a*l., 2022)**. The value of K indicates that the growth rate of the blue swimming crab is slow, and it takes a long time to reach its maximum length. Different growth coefficients in crustaceans can be due to several factors that is age, genetics, and seasons that affect water temperature **(Sara *et al*., 2016)**. The results of research on growth parameters of the blue swimming crab (*P. pelagicus*) at different locations and times exhibit varying values (Table 2).

Total mortality rate (Z), natural mortality (M) and fishing mortality (F) in this study are lower than those obtained by **Iksanti *et al.* (2022)**, who recorded a total mortality rate (Z) of 2.99/ year, natural mortality (M) of 1.31/ year, and fishing mortality (F) of 1.68/ year for blue swimming crabs that landed at TPI Jepara. The total mortality rate (Z), natural mortality (M) and fishing mortality (F) of *P. pelagicus* caught in Bardawil Wetland, Egypt, recorded 4.68/ year, 2.25/ year, and 2.43/ year, respectively **(El-Betar, 2022**). The total mortality, natural mortality and capture mortality rates of *P. pelagicus* found in Egypt's Red Sea waters were 2,929/ year, 1,285/ year and 1,644/ year, respectively **(El-Kasheif, 2021)**. Fish species are more susceptible to activities of fishing rather than deaths caused naturally by predation, competition, and disease **(Ofori-Danson *et al.*, 2021)**. The exploitation pressure in a fishing area can also influence the dynamics of fish population parameters **(Ernaningsih *et al.*, 2022)**.

Table 2. Growth parameter of blue swimming crabs (*P. pelagicus*) in different locations and times

Researcher/year	Location	K (yr^{-1})	Lmaks (cm)
Kembaren/2012	Bone Bay	1,27	15.9
Sara/2017	Southeast Sulawesi Waters	0.55	16.9
Tirtadanu/2019	Indonesia	1,24	-
Abrenica/2021	Philipines	1,30	21,65
Rabaoui/2021	Saudi Arabian	2,12	-
Kasheif, 2021	Red Sea, Egypt	0,41	21.19
El-Betar/2022	Egypt	1,40	16.60
The present study/2023	Bawasalo, Pangkep	0,41	15.10

The ratio of exploitation is very important to estimate the state of the stock is optimal, under exploitation or over exploitation **(Mehanna *et al.*, 2019)**. The ratio of exploitation of *P. pelagicus* found in this study in Bawasalo waters, Pangkep Regency, is 0.55, indicating that exploitation ratio exceeds the optimal limit (MSY). Interviews with local fishermen revealed that the intensity of blue swimming crab capture is quite high, with fishermen catching every day using several types of fishing gear. In the Tiworo Strait, the population of blue swimming crab is categorized as experiencing moderate exploitation **(Permatahati *et al.*, 2020)**.

CONCLUSION

The distribution of carapace width ranged from 6.70 to 13.80cm, with the highest proportion observed at carapace widths between 9.10 and 9.60cm (19.7%), and the lowest proportion at widths between 13.3 and 13.8cm (0.2%). Carapace widths less than 10cm accounted for 66.69% of the captures, while widths greater than 10cm accounted for 33.31%. The carapace width-to-weight relationship was computed as $W = 0.1038L^{2.7334}$, indicating a negative allometric growth. The growth rate is low, and the mortality rate of arrests exceeds the natural mortality rate. The exploitation ratio is at the limit of the maximum exploitation (MSY).

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