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Research Article

Growth, mortality, and exploitation rate of blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) in Jepara Regency, Central Java, Indonesia

Saputra S.W.[1], Ayuningrum D.[1*], Sabdaningsih A.[1], Redjeki S.[2]

[1]Department of Aquatic Resource, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Tembalang, Semarang, Postcode: 50275
[2]Department of Marine Science, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Tembalang, Semarang, Postcode: 50275
*Correspondence: diahayuningrum21@lecturer.undip.ac.id

Keywords

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Exploitation,
Growth,
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Recruitment

Abstract

Regarding the exploitation of blue swimming crab (*Portunus pelagicus*) resources in the Java Sea in the last decade, it is presumed to be overfished. This study aims to analyze population dynamics by examining the relationship between carapace width and weight, recruitment patterns, the carapace width at first capture (CWc), growth parameters, mortality rate, and the exploitation level of *P. pelagicus*. The study was conducted in the north coastal waters of Jepara Regency, Indonesia, from May to September 2022 and February to August 2023. A survey method and direct observations were used to sample the catch area. The growth and mortality rate parameters were estimated from carapace width frequency data and analyzed using ELEFAN I software in the FiSAT II program package. The results showed that the relationship between carapace width and weight was positively allometric, following the equation $W = 0.000053 \times CW^{3.05}$. The carapace width at first capture (CWc) was estimated to be 110.5 mm. Peak recruitment occurred in August–September. The infinite carapace width (CW∞) was estimated at 189 mm, with a growth curve index of 1.6. The crab followed the von Bertalanffy growth function (VBGF) of $CWt=189\ (1-e^{(-1.6(t+0.0584)})$. The total mortality was estimated at 4.46 yr^{-1}, fishing mortality at 3.03 yr^{-1}, and natural mortality at 1.43 yr^{-1}. The exploitation rate (E) was 0.68. This indicates that the rate of exploitation of *P. pelagicus* has exceeded the maximum sustainable yield (E=0.5) and is overexploited.

Article info

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Introduction

The blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) is a species within the family *Portunidae* that inhabits shallow waters up to a depth of 16 m, with a substrate consisting of mud, sand, and muddy sand (Asphama *et al*., 2015). Blue swimming crabs are found in coastal waters, extending up to the continental shelf in muddy estuary ecosystems, sand, or seagrass beds at depths of up to 50 m. Crabs are one of the significant export commodities, ranking as the fourth largest, and most of their production comes from wild capture fisheries. Crabs are a commodity with a high economic value and are exported in frozen and processed products. Crab resources fishing often prioritizes economic benefits and short-term gains, with little consideration for the sustainability of crab resources and ecosystems (Kangas, 2000; Huda *et al*., 2021).

The coastal waters of Jepara Regency are located within the Java Sea (WPP 712). According to the regulations of the Minister of Maritime Affairs and Fisheries (MMAF) No. 19 of 2022, the estimated resource potential for blue swimming crab in the Java Sea (WPPNRI) is 23,508 metric tons. The allowable catch quota in 2022 was set at 16,456 metric tonnes, and the utilization rate has reached full exploitation (E = 0.7). Tirtadanu and Suman (2017) reported that the exploitation rate of blue swimming crabs in Kotabaru Waters, South Kalimantan, Indonesia, was 0.68 for males and 0.77 for females, indicating overfishing. This situation underscores that blue swimming crab harvesting in the Java Sea has been over-exploited and emphasizes the need for improved preventive measures.

In addition to the high fishing rate, another issue threatening the sustainability of the blue swimming crab is the use of various fishing gear. The fishing gear includes fixed gill nets, crab nets, crab trawls, bottom set gillnets, traps, small beam trawls, pocket drag nets, and dredges. Blue swimming crabs are also a by-catch of other fishing gear, such as trammel nets, pocket drag nets, *dogol*, and *sero* (Nuraini *et al*., 2009). Among the various types of fishing gear, the most non-selective and environmentally unfriendly are crab pots, traps, small beam trawls, pocket nets and dredges (Zairion *et al*., 2015; Kamelia and Muhsoni, 2020; Huda *et al.*, 2021). On the other hand, the number of fishermen in Teluk Awur Village, Jepara tends to increase, so the exploitation rate is rising. This condition has an impact on increasing pressure on blue swimming crab resources, which will lead to depletion (de Lastang *et al*., 2010; Budiarto *et al*., 2015; Susanto *et al*., 2019). This study aims to analyze crab stocks by estimating growth parameters, recruitment patterns, the natural mortality rate (M), fishing mortality rate (F), total mortality rate (Z), and exploitation level (E) of *P. pelagicus* in the northern waters of Jepara Regency, Central Java, Indonesia.

Materials and methods

Sampling methods

This study was conducted from May 2022 to September 2022 and from January 2023 to August 2023, in the coastal waters of Jepara Regency, Central Java, Indonesia. The crab fishing area is located approximately 8–12 km from the coastline.

Crabs from the catches of all Teluk Awur and Kartini coastal waters and landing sites (Fig. 1) were transported to the laboratory. The sampling method employed systematic random sampling. A random sampling approach was used to select individual crabs, ensuring that each crab in the catch had an equal chance of being selected.

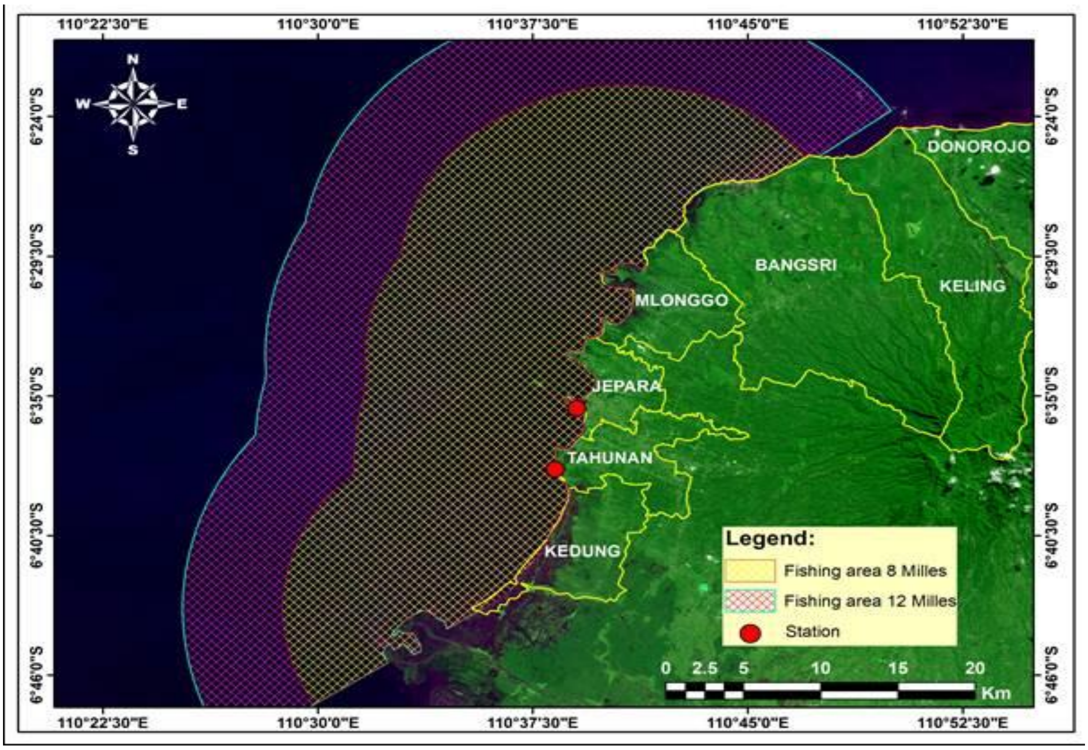

Figure 1: Map of sampling locations.

Data collection

Carapace width was measured in the laboratory using a caliper with an accuracy of 0.5 mm. The weight data of the blue swimming crab was measured using an electric scale with an accuracy of 0.01 g. Carapace width data for frequency analysis was measured in the field using millimeter grid paper.

Data analysis

The carapace width-weight relationship was determined according to the equation provided by Sparre and Venema (1998), where W = a × L^b

$$Log\ W = Log\ a + b\ Log\ L$$

Here, *W* represents weight, *a* represents the intercept, *b* represents the slope, and *L* represents the carapace width. The data for the carapace width distributions of crabs were analyzed using FiSAT II. The parameters of the von Bertalanffy growth function (VBGF) were as follows:

$$Lt = L\infty\ (1 - e - K(t - to))$$

Where, $L\infty$ represents the asymptotic length, e is the exponential constant, K is the growth rate coefficient, t is the age, and t_0 is the age at length 0 (null). The theoretical age at length zero (t_0) was obtained from Pauly's equation (Pauly, 1980):

$$Log\ (-to)\ =\ -0.392 - (0.275\ log\ L\infty) - (1.038\ log\ K)$$

To obtain the carapace width at the first capture using the frequency distribution of carapace width, data were analyzed using the standard equation (Sparre and Venema, 1998), where the width class with the highest carapace width (CW) value represents the carapace width of the first captured blue swimming crab (CWc). The mathematical model of the equation is as follows:

$$F(c)\ =\ (ndL/s\sqrt{2}\pi)\ \times\ e-((L'-L)^2)\ /2s^2$$

In this equation, *F(c)* represents the frequency of the carapace width class, *n* is the number of samples, *dL* is the carapace width class interval, *s* is the standard error, *π* is the constant 3.14, and *L'* is the middle value of the carapace width class. The total mortality rate (Z) is estimated using the catch curve method, which is then converted to width (Pauly, 1980). The mathematical equation is:

$$Ln\left[\frac{F}{dt}\right]\ =\ constant - Zt$$

A length-based catch curve is a plot between *Ln(F/dt)* against *t*, where *F* represents the number of individuals in each age class, and *t* is the relative age. The value *dt* represents the time taken for the blue swimming crab to grow through a particular carapace width class. The natural mortality rate (M) is estimated using Ivanov's method, which shows a close association between M and $T_{m50\%}$. The equation is as follows:

$$[\,M = \frac{1.521}{(T_{m50})^{0.720}} - 0.155\ \text{per year}]$$

Here, t_{m50} represents the age of maximum biomass, which is the age (carapace width) at which the first maturity occurs. All these methods are incorporated into the FISAT II software.

Results

Structure of carapace width

Crabs caught during the study had carapace widths ranging from 39 mm to 225 mm (Fig. 2). The samples consisted of 1,362 individuals and the median was 111 mm, the mode was 120 mm, and the standard error was 23.22 mm. The description of *P. pelagicus* during the period from May 2022 to August 2023 is presented in Table 1. The largest mean was found in August (123.9 mm) with the smallest standard error.

The carapace width at first capture (CW_c)

The carapace width at first capture was estimated at 110.5 mm (Fig. 3). This indicates that 50% of crabs smaller than 110.5 mm should escape captivity, while 50% of those larger than 110.5 mm are captured. Based on the size structure of the blue swimming crabs caught, it is evident that the carapace width caught was greater than the carapace width of the first capture (CW_c).

The carapace width-weight relationship and condition factors

The relationship between carapace width (mm) and weight (gr) has been calculated, resulting in an intercept (a) of 0.000053 and a slope (b) of 3.05. Therefore, the equation for the carapace width-weight relationship in *P. pelagicus* is expressed as:

$W=0.000053\times L^{3.05}$ (Fig. 4).

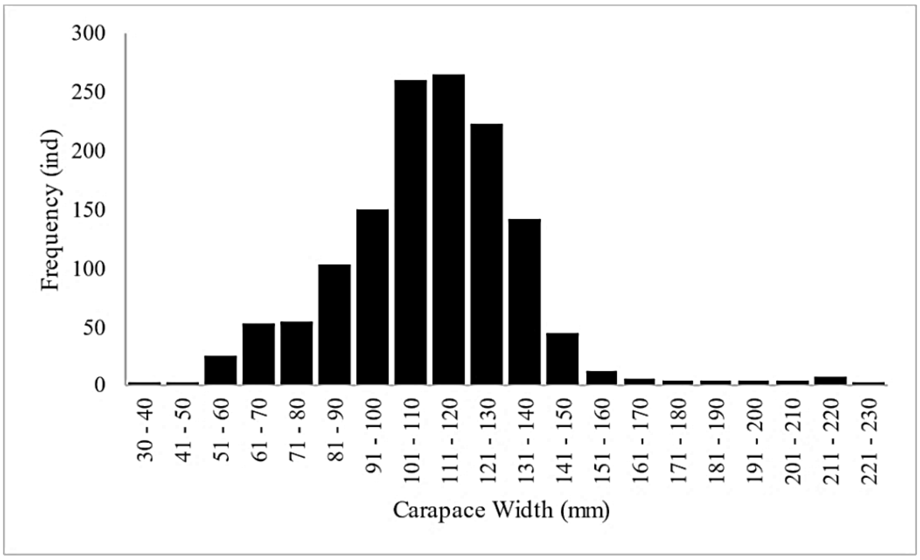

Figure 2: The frequency distribution of carapace width of *P. pelagicus* in the waters of Jepara Regency, Central Java, Indonesia.

Table 1: The description of *P. pelagicus* during the period from May to September 2022 and January to August 2023 in Jepara waters, Central Java, Indonesia.

No.	Month	Number of samples	CW range (mm)	Mean CW (mm)	SE
1	May ‘22	125	95–190	112.0	14.5
2	Jun ‘22	106	75–138	102.0	11.8
3	Jul ‘22	150	82–141	114.5	12.7
4	Aug ‘22	109	98–148	123.9	8.5
5	Sep ‘22	161	100–162	127.1	12.8
6	Jan ‘23	83	48–127	80.1	20.6
7	Feb ‘23	106	39–219.5	93.2	33.3
8	Mar ‘23	101	75–225	117.6	33.4
9	May ‘23	45	75–126	99.0	12.1
0	Jun ‘23	121	80–147	108.3	20.5
11	Jul ‘23	104	60–153	99.4	21.6
12	Aug ‘23	151	72–153	116.0	19.5

The value of b=3.05. Based on the t-test of the b value, the t-count was 0.72 while the t-stat was 37.72 indicating that the crab exhibits isometric growth, meaning that the growth in weight is proportional to the growth in carapace width. The following equation results in a condition factor (K) of 1.16 for the blue swimming crab in the waters of Jepara, Central Java, Indonesia:

$$K=\frac{W}{L^3}$$

Recruitment pattern of P. pelagicus

The monthly percentage of *P. pelagicus* recruitment pattern is depicted in Figure 5. Blue swimming crab captures in the northern waters of Jepara, Central Java, Indonesia, take place consistently throughout the year, with a peak occurring in August and September.

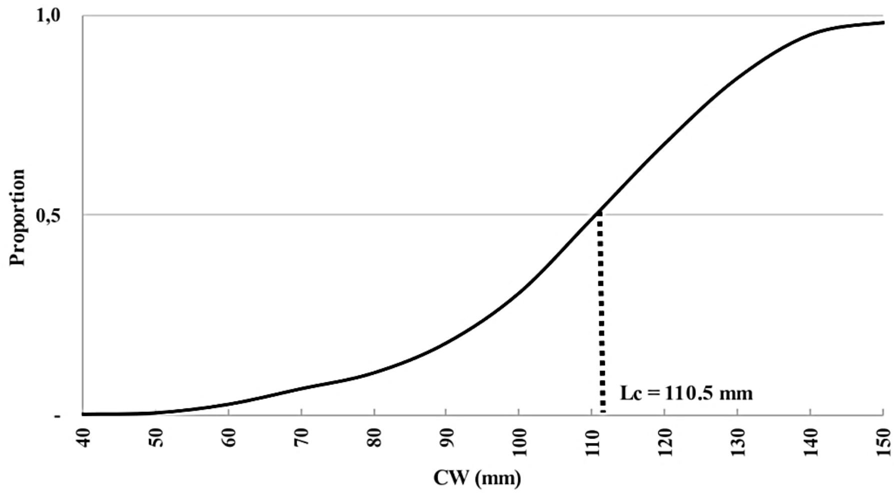

Figure 3: Estimated $L_{c50\%}$ of *P. pelagicus* in the waters of Jepara Regency, Central Java, Indonesia.

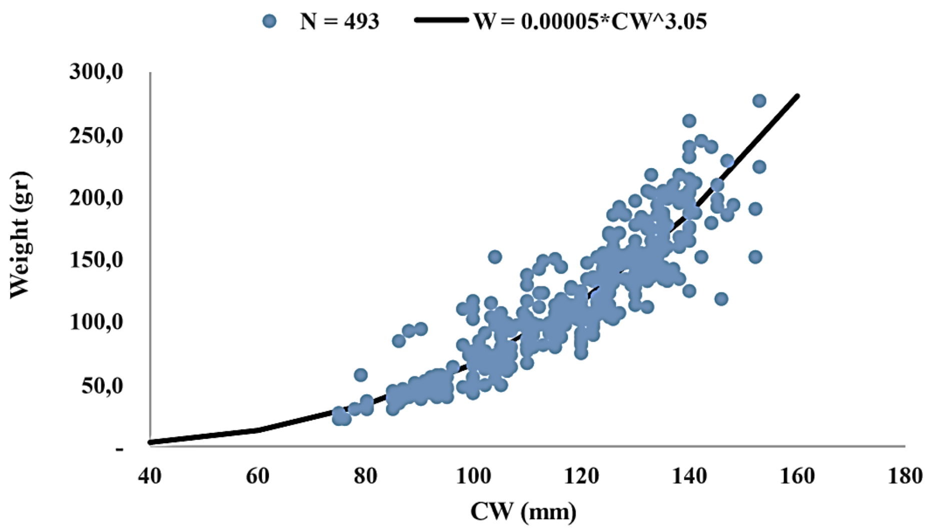

Figure 4: The curve of the carapace width (mm) and weight (g) relationship of *P. pelagicus* in the waters of Jepara Regency, Central Java, Indonesia.

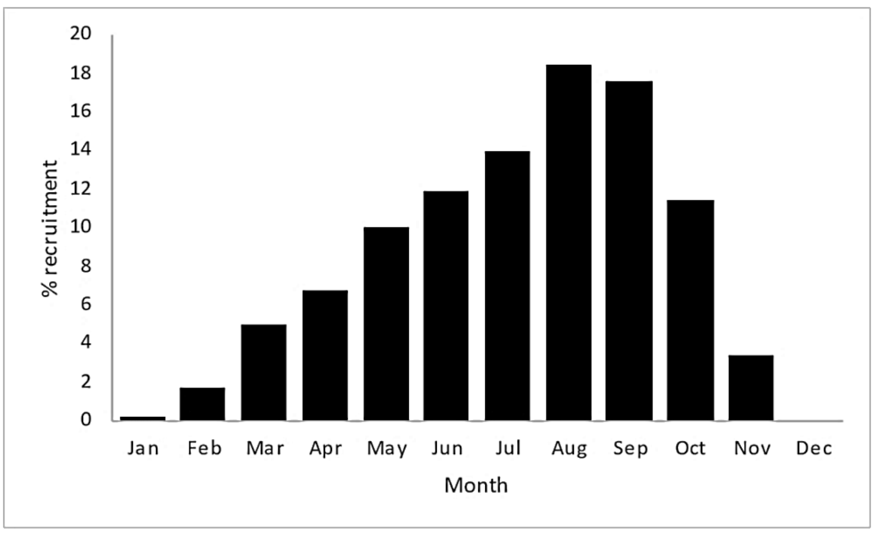

Figure 5: Yearly recruitment pattern of *P. pelagicus* in the waters of Jepara Regency, Central Java, Indonesia.

Growth parameters

The growth curve was determined based on the equation as illustrated in Figure 6. The values are as follows: infinite carapace width (CW∞) was 189 mm, K was 1.6 yr^{-1}, and t_0 was -0.0584 yr. The growth equation for *P. pelagicus*, following the VBGF, is expressed as:

$$Lt = 189\,(1 - e^{-1.6(t+0.0584)})$$

Based on the results of this study, it is evident that the K value is relatively large, indicating a relatively fast growth rate. With a value of K=1.6 yr^{-1}, the carapace width at first capture (CWc=110.5 mm) is attained at the age of 0.49 years (equivalent to 5 months and 27 days), while the asymptotic carapace width (L∞=189 mm) is achieved at the age of 6 years (Tables 2 and 3).

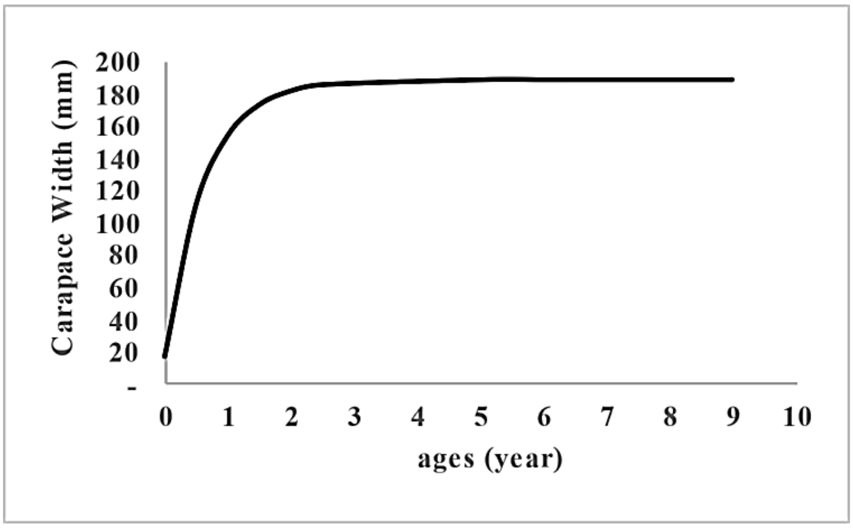

Figure 6: The von Bertalanffy growth curve of *P. pelagicus* in the waters of Jepara Regency, Central Java, Indonesia.

Table 2: Relationship between carapace width and weight Parameters of Blue Swimming Crab.

Reference	Location	Carapace length	b	Growth pattern
This study	Jepara, central Java Indonesia	63 – 190	3,0500	Isometric
Safira *et al*. (2019)	Cirebon West Java Indonesia Male female	71 – 154 92 – 152	3.0489 3.4299	Isometric Positive allometric
Rahman *et al*. (2019)	Lamongan East Java Inonesia Male female	50 – 190 50 – 190	3.0535 2.9800	Isometric Isometric
Mehanna *et al*. (2013)	Oman coastal waters Male Female Total	57 – 193 84 – 206 57 - 206	3.0061 3.2401 3.2109	Isometric Positive allometric Positive allometric
Noori *et al*. (2015)	Iran Gulf Male female	80.8 – 123.8 84.5 – 263.4	3.4500 3.0300	Positive allometric Isometric

Table 2 (continued):

Reference	Location	Carapace length	b	Growth pattern
Sawudee and Songrak (2009)	Coastal area of Trang Province Thailand Male Femal Total	55 - 170	3.2192 3,1860 3.2024	Positive allometric Positive allometric Positive allometric
Ningrum *et al.* (2015)	Betahwalang Demak Total	74 – 181	3,166	Positive allometric
Kamelia and Muhsoni (2020)	Bancaran, Madura	50.4 – 138.2	2.8368	Negative allometric
Kunsook *et al*. (2014)	Kung Krabaen Bay Thailand Male Female		2.9211 2.8944	Negative allometric Negative allometric

Table 3: The relationship between age (year) and carapace width of *P. pelagicus* in the waters of Jepara, Central Java, Indonesia.

No.	Age (year)	CW (mm)
1	-0.0584	0
2	0	16.9
3	0.21	66.0
4	0.28	79.0
5	0.35	90.7
6	0.42	101.1
7	0.5	110.5
8	0.56	118.7
9	0.63	126.2
10	1	154.2
11	2	182.0
12	4	188.7
13	6	189.0
14	8	189.0
15	10	189.0

Mortality and utilization rate of blue swimming crab

The total mortality rate (Z) of the crab *P. pelagicus* is estimated at 4.46 per year, with natural mortality (M) equal to 1.43 per year and fishing mortality (F) equal to 3.03 per year (Fig. 7). The exploitation rate (E) was estimated using the equation E=F/Z, resulting in E = 0.68. The value of E indicates that the crab stock is over-exploited. The exploitation rate is considered optimum when E=0.5. This result indicates that the exploitation pressure on *P. pelagicus* has exceeded the sustainable limit.

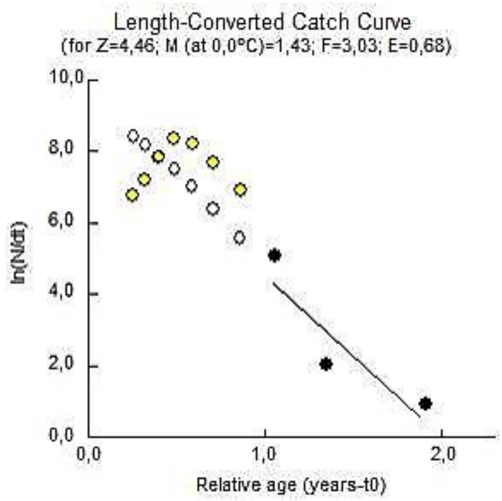

Figure 7: The length-converted catch curve of *P. pelagicus* in the waters of Demak-Jepara, Central Java, Indonesia.

Discussion

The results of calculating the relationship between carapace width and crab weight obtained a coefficient of b = 3.05. This value indicates that the growth pattern of crabs during the study was isometric. This is supported by a condition factor value above 1 (K=1.16 per year). This indicates that the habitat and aquatic environment of Jepara Regency are suitable for *P. pelagicus*. Several studies have obtained similar results, indicating that the growth pattern of the crab is isometric (Table 2). Table 2 showed that most of the blue swimming crab growth patterns tend to be isometric and positive allometric. Negative allometric growth patterns are only found in the waters of Madura, East Java, Indonesia and Krabaen Bay, Thailand.

The carapace width at first capture by *bubu* (trap) was 110.5 mm. The mean carapace width at first maturity (CWm) in the Java Sea was 106 mm, with the lowest CWm of female blue swimming crabs caught in Cirebon and the highest in Sampit (Ernawati *et al*., 2017). Munthe and Dimenta (2022) found that male *P. pelagicus* reach first maturity at 87.20 mm CW, while females reach it at 103.55 mm CW. Based on the CWc, it is evident that the size of the crabs caught is >50% mature because of CWc>CWm. This condition indicates that more than 50% of the caught crabs have already spawned.

Ningrum *et al*. (2015) conducted a study in the waters of Betahwalang, Demak Regency, and obtained a CWc value of 122 mm. Ernawati *et al*. (2017), in Pati waters, found that the CWc from traps was 108 mm. Suhernalis *et al*. (2020) obtained smaller values for $L_{(c50\%)}$, namely 75.1 mm (male) and 83.6 mm (female) in the northern waters of West Java. Nuraini *et al.* (2009) found that the CWc of blue swimming crabs caught by *bubu*, fixed lift net, beach seine, and monofilament gill net were 63 mm, 73 mm, 86.9 mm, and 89.6 mm, in Jakarta Bay respectively. Kunsook *et al*. (2014), in Kung Krabaen Bay, Gulf of Thailand, reported a $CW_{(C50\%)}$ from crab traps and crab gill nets of 69 mm and 111.3 mm, respectively. Mehanna *et al*. (2013), found blue swimming crabs (*P.pelagicus*) CLc, 44 mm, which corresponds to an age of 4–5 months, while the Lm was 60–65 mm (at 6–7 months) in the coastal waters of Oman.

P. pelagicus capture is estimated to occur almost throughout the year, with the peak season in August–September. Kamelia and Muhsoni (2020) reported that *P. pelagicus* observed a single capture season in June–August,in the waters of Bancaran Bangkalan Madura Village, with a sampling frequency of 3 times (December 2019–February 2020), which is similar to this study. Nurdin *et al.* (2019), in their research in the waters of Salemo Island, South Sulawesi, with 5 samplings (March–July), observed the peak of the single crab capture season in August-September. Kunsook *et al*. (2014), in Kung Krabaen Bay, Gulf of Thailand, found that captures occurred in two peaks throughout the year. Abrenica *et al*. (2021), in Danajon Bank, Central Philippines, found that the capture pattern showed two peaks, with the primary peak occurring in April–May and the secondary peak happening in August–September. Apart from monthly fluctuations, blue swimming crab production also occurs on an annual basis. Mehanna *et al.* (2013) showed that blue swimming crab production has fluctuated over the last 23 fishing seasons. The lowest production was in 1996, with a tendency to increase, and production peaked in 2009. Production then fell drastically until 2015 but increased very sharply the following year (2016).

The growth parameters of the blue swimming crab including CW∞, K and t_0 were estimated at 189 mm, 1.6 yr^{-1} and -0.0584 year, respectively. The relationship between L∞ and K is that the higher the K value, the faster the fish will reach L∞. Some studies of blue swimming crabs have found smaller K values. Kamellia and Muhsoni (2020) obtained CW∞=195 mm and K=1.32 yr^{-1} based on catch data collected at the fish landing site in Bancaran Bangkalan village. Kunsook *et al*. (2014), in Kung Krabaen Bay, Gulf of Thailand, obtained L∞=167.3 mm and K=1.13 yr^{-1}. Tirtadanu and Suman (2017), in Kotabaru Waters, South Kalimantan, found that the CW∞ of *P. pelagicus* was 179.2 mm CW for males and 183.6 mm CW for females. The growth rate of the crab (K) was 1.36 yr^{-1} for males and 1.11 yr^{-1} for females. Mehanna *et al*. (2013) reported that the blue swimming crab (*P. pelagicus*) in the coastal waters of Oman obtained a CLc value of 44 mm, corresponding to an age of 4-5 months, while the Lm was 60-65 mm (at 6-7 months).

On the contrary, some studies have reported higher K values. Kunsook *et al*. (2014) in Kung Krabaen Bay, Gulf of Thailand obtained the growth parameters for male crab as L∞=142.6 mm and K=2.75 yr^{-1}. Mehanna *et al.* (2013) found blue swimming crab (*P. segnis*) in the coastal waters of Oman and obtained the values of K and L∞ for males, females, and combined sexes as 1.85 yr^{-1}, 1.68 yr^{-1} and 1.68 yr^{-1} and 102.83 mm, 109.57 mm and 108.46 mm, respectively. Mehanna and Al-Aiatt (2011) found K=2.04 yr^{-1} and L∞=83.8 mm CL in Bardawil Lagoon. Sawudee and Songrak (2009) in the coastal area of Trang Province, Thailand, found growth parameters for *P. pelagicus* as follows: for males, L∞=179 mm OCW and K=1.5 yr^{-1}, for females, L∞=171 mm OCW and K=1.6 yr^{-1} and for combined males/females, L∞=173 mm OCW and K=1.5 yr^{-1}. The L value in this study was relatively larger and the K value relatively smaller, indicating that the time to reach L∞ was longer. The difference in growth rate can be attributed to variations in size, fishing area, and fishing time. Bakhtiar *et al*. (2013) added that differences in the growth speed of the same species in different waters could be influenced by environmental conditions.

The total mortality rate (Z) of *P. pelagicus* in this study was estimated to be 4.46 yr^{-1}, with natural mortality (M)=1.43 yr^{-1} and fishing mortality (F)=3.03 yr^{-1}. The exploitation rate (E) is 0.68 (Fig. 7). An E value of 0.68 indicates that the level of exploitation of blue swimming crabs in Jepara waters has exceeded the optimum limit or is over-exploited. The optimum exploitation rate is E=0.5. Several studies on blue swimming crab in the Java Sea have yielded similar results. Tirtadanu and Suman (2017) in Kotabaru waters, South Kalimantan, found that the utilization rate (E) of crabs was 0.68 for males and 0.77 for females, indicating over-exploitation. The results of this study are consistent with the regulation of MMAF number 19/2022, which states that the exploitation rate (E) of blue swimming crabs in the Java Sea (WPP 712) is 0.7. The results of research in the regional and international waters indicate that the exploitation rate is still below the optimum or under-exploited. Kamelia and

Muhsoni (2020), in the coastal waters of Bancaran Village, Bangkalan Madura, found an exploitation rate (E) of 0.45. Kunsook *et al.* (2014), in Kung Krabaen Bay, Gulf of Thailand, reported that the exploitation rate for male and female crabs was estimated to be 0.56 and 0.7 yr^{-1}, respectively. Mehanna *et al*. (2013), estimated the value of E equal to 0.61 for *P.segnis* using the Ricker method in the coastal waters of Oman.

Conclusions

Based on the results and comparisons with existing literature, it can be concluded that the growth of *P. pelagicus* in the Coastal Waters of Jepara Regency Central Java, Indonesia, is isometric growth. The *P. pelagicus* follows the VBGF: Lt=189[1-exp[-1.6(t+0.0584)]. The blue swimming crab capture in Jepara waters occurs throughout the year, with a peak in August–September. The fishing mortality rate is greater than natural mortality, so the exploitation level is above optimum (E=0.68), indicating that it is overexploited.

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Conflicts of interest

Authors declare no conflict of interest.

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