An initial population parameter estimation of *Portunus pelagicus* on the eastern coast of Aceh

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Abstract. Conventional stock assessment models require large amounts of historical catch and effort data, which are often unavailable for small-scale fisheries such as the blue swimming crab (*Portunus pelagicus*) fishery on the east coast of Aceh. The lack of stock assessment models applicable to many fish species with limited data, such as the BSC, has hindered policymakers' ability to monitor fish stock status more effectively. When historical catch data, abundance indices, or age-composition data are unavailable, stock assessment methods can be employed using size and/or life history information. This study aimed to determine the stock status of *P. pelagicus* using limited data, focusing on the length-based spawning potential ratio. Data were collected periodically at several crab landing sites along the eastern coast of Aceh. Based on the life history parameters analyzed, the crab stock was categorized as overexploited (red flag), with an SPR < 0.2 (20%). In line with this assessment, the crab exploitation ratio (F/M) was high at 1.85, with an exploitation rate (E) of 0.71, indicating overfishing. Management actions to reduce crab fishing effort are necessary to improve the status of the stock and achieve a healthier stock.

Keywords: Population dynamics, immature catches, mangrove ecosystems.

1 Introduction

The blue swimming crab (BSC) *Portunus pelagicus* is a vital fishery commodity that plays an essential role in several Indo-Pacific regions, including Indonesia [1, 2]. BSC are often found in several habitats and generally live in estuaries to offshore areas at depths of up to 50 m. They are often found in coastal areas with sandy to muddy substrates covered with seagrass and algae [3, 4].

The BSC is also an export commodity with high economic value, along with tuna and penaeid shrimp. Its natural stocks are expected to continue to meet domestic and foreign

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demand. One of the importing countries for this commodity is the United States, where Indonesia accounts for 40% of BSC demand. As much as 80% of Indonesian BSC products are sent directly to this country [5–7], and the BSC in the Indonesian Fisheries Management Area (WPPNRI) 571, located in the Malacca Strait, is one of its production centers. The city of Langsa is an essential landing site in this fishery management area.

The utilization of *P. pelagicus* on the eastern coast of Aceh is still generally carried out on a small scale. Fishers use folding traps and bottom gillnets to capture these resources. The fishing fleet is also simple, with relatively short distances from fishing grounds. Small-scale fisheries interact significantly with aquatic conservation areas, including mangrove ecosystems on the east coast of Aceh.

Monitoring fish stock status is crucial for promoting sustainable BSC fishery management [8]. This is done by assessing stock status relative to management reference points using stock assessment models. Conventional stock assessment models require large amounts of data, including historical catch and effort data, which are often unavailable for some exploited fishery commodities, particularly those caught in small-scale fisheries [9–13].

Most fish stock assessments with good data are available only for regions such as North America, Europe, and Oceania, particularly Australia and New Zealand. In contrast, stock assessments in the other areas, including Indonesia, are severely underrepresented [14, 15]. The lack of stock assessment models applicable to many fish species with limited data, such as the BSC in Aceh, has hindered policymakers' ability to monitor fish stocks more effectively. If not adequately addressed, this problem could increase the risk of depletion of wild fish stocks or biological extinction due to inaccurate management actions. Simultaneously, resource exploitation has already reached excessive levels.

Fish stock assessment with limited data has been a significant research topic over the last decade, during which several new methods have been developed [16]. When no historical catch data, abundance indices, or age composition data are available, stock assessment methods use size and/or life history information, such as the length-based spawning potential ratio (LB-SPR) method [10, 12], length-based integrated mixed effects model (LIME) [17], mean length-based mortality estimator (MLZ) [18], and the fraction of mature fish in the catch and other similar practical tools [19]. This study aimed to determine the stock status of *P. pelagicus* using limited data by employing the length-based spawning potential ratio (LB-SPR).

2 Methods

2.1 Sampling sites

Data were collected periodically at several BSC landing sites in Langsa City, Aceh, Brazil. Thus far, information indicates that the BSC landings in this city are concentrated in Kuala Langsa. Specimens for reproductive biology analysis were obtained and analyzed at the Genetics and Aquatic Biodiversity Laboratory, Faculty of Marine and Fisheries, Universitas Syiah Kuala. This in situ data collection was conducted from August to October 2025.

2.2 Data collection

The selection of fishing fleets to be observed for their catch results used a stratified random sampling method, in which fleets from each landing location were first stratified by fleet type, fishing gear type, and fishing area. This method provides a wider size range for crab catches and avoids significant bias in estimating gonadal maturity size [1].

Biological observations included measuring carapace width (**Fig. 1**), individual weight, sex, female gonadal maturity, and the presence of eggs in the abdomen of female crabs (berried females) [1, 20, 21]. The sex of male and female crabs was distinguished by secondary sexual characteristics, namely, by looking at the shape and color of the abdomen and the pleopod hairs on the abdomen [22].

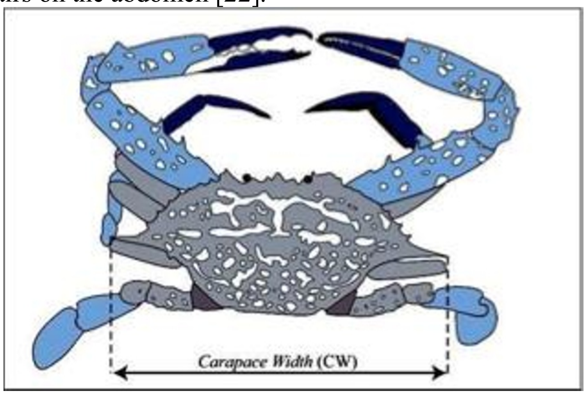

Fig. 1. Carapace width measurement of *P. pelagicus*.

2.3 Data analysis

The size at first capture (L_c) was calculated using the Sparre and Venema [23] equation. In contrast, the size at first gonadal maturity (L_{50}) was calculated by entering the carapace width and PL_m data values into a logistic function graph [24]. The two equations above are used to determine the average size of the captured and gonadally mature crabs functionally by creating a cumulative frequency of each crab carapace width, thereby obtaining a standard logistic curve, where the intersection point between the curve and the 50% cumulative frequency is the carapace width when 50% of the crabs are captured and gonadally mature [1].

The results of the analysis of length at first capture (Lc), length at first maturity (L_m or L_{50}), and population parameters were used as inputs for the LB-SPR model [9, 10]. The population parameters required include the asymptotic carapace width ($L\infty$), von Bertalanffy growth coefficient (k), theoretical age when the crab length is zero (t_0), intercept of the length-weight relationship (a), slope of the length-weight relationship (b), natural mortality rate (M), fishing mortality rate (F), and maximum age of crabs.

The growth rate (k), asymptotic carapace width ($L\infty$), and crab lifespan at length 0 (t0) were obtained from the distribution of the crab size caught each month. These three parameters determine the growth function of von Bertalanffy [25]:

$$Lt = L\infty\,(1 - e^{-k\,(t-to)}) \qquad (1)$$

where,
Lt = crab length at t (mm)
$L\infty$ = infinity length (mm)
k = growth rate

The previously calculated crab growth parameters were used as inputs to create a catch curve, enabling estimation of the total mortality rate (Z). The value of Z is primarily determined by the rate of fishing mortality (F), which is determined by the level of effort required to catch fish resources [25]. The catch on fishery stocks will reach a sustainable maximum if the mortality due to capture is equal to natural mortality (F = M); thus, the exploitation rate will be optimal if E = F/2F or $E_{opt} = 0.5$ [23].

The size (length) when first caught (L_c) was calculated using the Sparre and Venema equation, and the size at first gonad maturity (L_m) was calculated by entering the data values for carapace width and Lm into a logistic function. Both the previously mentioned equations examine the mean size of captured swimmer crabs and their functional gonad maturity by constructing cumulative frequency distributions of each swimmer crab's carapace width, which yield basic logistic curves.

These population parameter values were used as inputs for LB-SPR modelling. To calculate the spawning potential ratio (SPR), biomass was calculated for each length group, and the spawning stock biomass (SSB) was determined. The SPR value of the analysis ranged from 0 to 1 or 0 to 100% in percentage terms. The SPR value of fish before fishing activities reaches 100% of its natural potential; if fishing has already occurred, reproductive potential will decline. The default standard for the reference point for teleost fish groups is 20% SPR, which, if exceeded, indicates a risk of recruitment decline; 30–40% and 50% SPR are proxy targets for maximum sustainable yield. The spawning potential ratio was estimated using the above analysis principle and online LB-SPR analysis (http://barefootecologist.com.au/lbspr) [10].

3 Results and discussion

The von Bertalanffy growth function for *P. pelagicus* was $L_t = 166.58[1\text{-}e^{-1.07(t+0.0992)}]$. **Fig. 2** shows that the maximum age at which crabs reach the eastern coast of Aceh is between 4 and 6 years old. Crabs experience growth stagnation, or in other words, crabs will experience natural mortality after reaching 6 years of age.

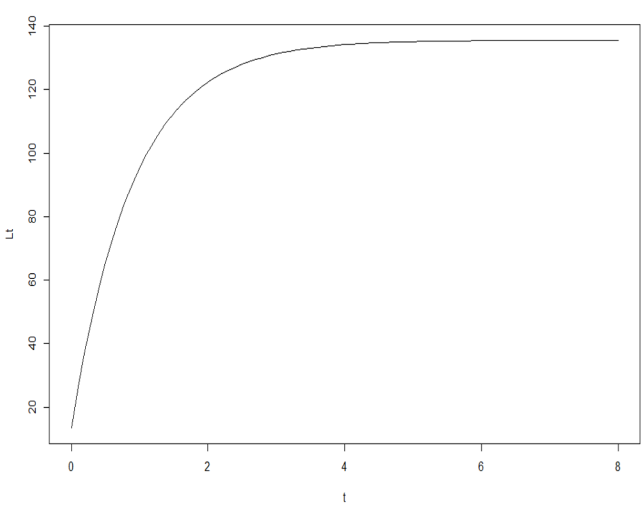

Fig. 2. The von Bertalanffy growth function of *P. pelagicus* on the eastern coast of Aceh.

The previously calculated growth parameters for *P. pelagicus* were used as inputs to create a catch curve, thereby obtaining an estimate of the total mortality rate (Z) (**Fig. 3**). The value of Z is primarily determined by the fishing mortality rate (F), which is in turn determined by the level of fishing effort on fish resources. The F value was 2.43/year, used to calculate the exploitation rate (E) of 0.71/year.

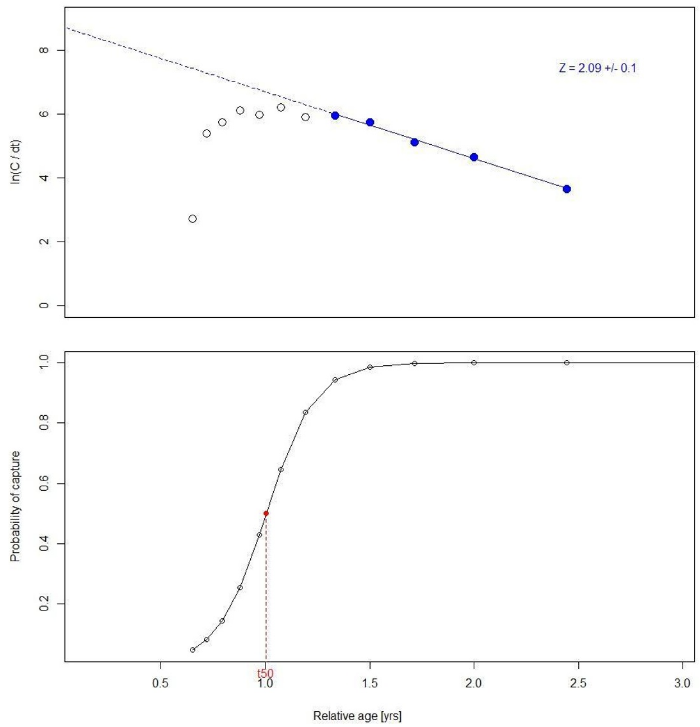

Fig. 3. The curve determining the total mortality rate as the basis for determining the utilisation rate of *P. pelagicus* on the eastern coast of Aceh.

Data on female *P. pelagicus* in the gonadal maturity phase (Phases 3 and 4) were then analyzed to determine the length at first gonadal maturity (L_{50}), which was subsequently compared with the length at first capture (Lc). The analysis showed that the Lc value of *P. pelagicus* on the eastern coast of Aceh was 106.10 mmCW, and the L_{50} was 113.41 mmCW. These results determine the minimum legal size (MLS) of *P. pelagicus* that can be caught on the eastern coast of Aceh (**Fig. 4**).

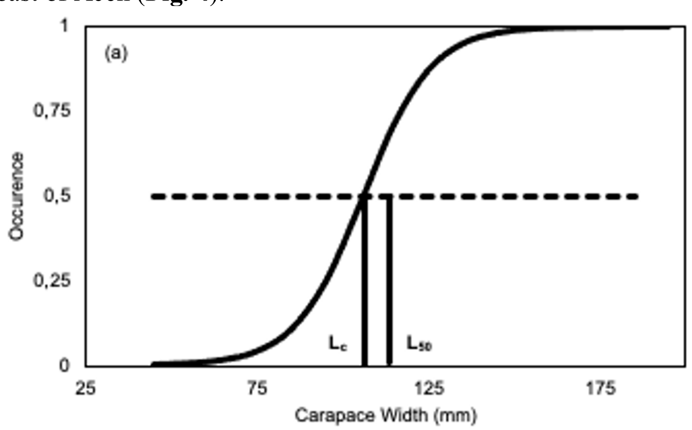

Fig. 4. First captured carapace width (Lc) and length at first gonadal maturity of *P. pelagicus* on the eastern coast of Aceh.

An analysis of stock conditions and population parameters was conducted on blue swimmer crabs from the eastern coast of Aceh. The stock condition analysis was based on population parameters estimated from the carapace length data. Fishery stock estimation was conducted using a length-based assessment approach.

The length data were time-series data collected during *P. pelagicus* landing activities. The fishery indicators used to estimate the stock condition of tiger prawns were the exploitation rate (E), ratio of fishing mortality to natural mortality (F/M), which was further defined as fishing pressure, and spawning potential ratio (SPR) [9].

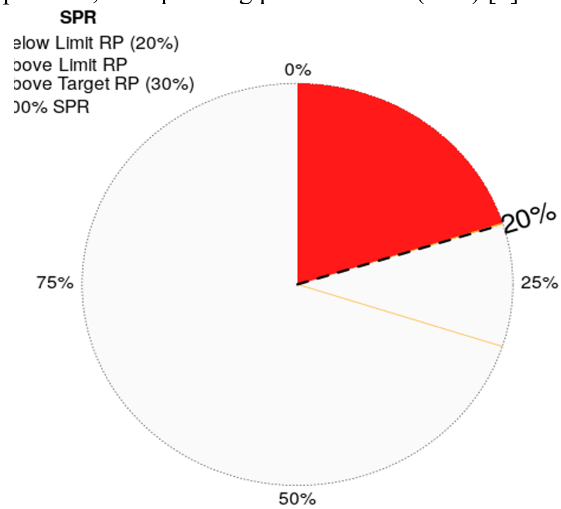

Fig. 5. Spawning potential ratio estimation of *P. pelagicus* on the eastern coast of Aceh.

The results of the analysis of growth parameters and SPR values indicate the condition of the fish resource: under-exploited (green), fully exploited (yellow), or over-exploited (red). Based on the analysis results presented in **Table 1**, the condition of the *P. pelagicus* stock on the eastern coast of Aceh is in the over-exploited (red) category owing to SPR values < 0.2 (20%). This indicates that the availability of mature crabs ready to spawn in nature is low. This is because many crabs are caught before they reach gonadal maturity or spawn at least once. Additionally, excessive fishing of egg-bearing crabs contributes to this overexploitation.

Table 1. Population parameters and stock condition estimation of *P. pelagicus* on the eastern coast of Aceh.

No.	Parameter	Estimation Result
	Length-based indicators (mmCW)	
1.	L_{min}	78.8
2.	L_{max}	162.3
3.	$L_{rata\text{-}rata}$	118.5
4.	L_m	113.41
5.	L_C	106.10
6.	L_{opt}	117.33
7.	L_{Copt}	115.67
	Growth parameters	
8.	Linf	166.58
9.	K	1.07
10.	t_0	0.0992

No.	Parameter	Estimation Result
11.	A_{max}	6
	Mortality parameters	
12.	M	1.31
13.	Z	3.88
14.	F	2.43
15.	E	0.71
16.	Persentase *immature* (%)	56
17.	F/M	1.85
18.	SPR	0.2

Remarks: L_{min}: minimum length of all measured samples (mm); L_{max}: maximum length of all measured samples (cm); $L_{average}$: average length (mm); L_m: length at first gonadal maturity (mm); L_c: length at first capture (mm); L_{opt}: optimal length (mm); L_{copt}: optimal length at first capture (mm); $L\infty$: asymptotic length (mm); k: growth coefficient ($year^{-1}$); t_0: age of shrimp when length = 0 (years); A_{max}: maximum age (years); M: natural mortality ($years^{-1}$); Z: total mortality ($years^{-1}$); F: mortality due to capture ($years^{-1}$); E: exploitation rate; %Immature: percentage of small shrimp caught before gonadal maturity; F/M: ratio of capture mortality to natural mortality; SPR: spawning potential ratio.

The minimum size limit (MLS) for *P. pelagicus* is an important measure to ensure the sustainability of this species along the eastern coast of Aceh. In general, Indonesia has established minimum carapace width requirements through the Regulation of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 7 of 2024 concerning the Management of Lobsters (*Panulirus* spp.), mud crabs (*Scylla* spp.), and BSC (*Portunus pelagicus*), whereby BSC fishing is directed at carapace widths above 100 mm or 10 cm. This minimum legal size (MLS) regulation is intended to preserve rajungan stocks by allowing small BSC to grow in the sea and mature BSC to be utilized by fishermen [26]. Apart from Indonesia, MLS are regulated in the Philippines with an MLS size of 102 mm CW [27] and in Vietnam with an MLS size of 100 mm CW [28]. The results of this study indicated that the Lm value exceeded 100 mm. Therefore, if the 100 mm MLS provision is applied, the BSC's spawning aggregate resource will be lower, potentially threatening the stock's sustainability. This study recommends increasing the MLS for the BSC to 110 mmCW or equivalent to a carapace width of 11 cm.

Other indicators used to describe the level of fish resource utilization were the F/M ratio and exploitation rate (E). The F/M ratio and exploitation rate are used to estimate fishing pressure on a population, and the optimal utilization rate or reference points are 1.0 (F/M) and 0.5 (E) for fishing under MSY (F = M) conditions [29]. The exploitation level of *P. pelagicus* on the eastern coast of Aceh was classified as high, with an F/M ratio of 1.85 and an exploitation rate (E) of 0.71. An F/M ratio > 1 indicates that the mortality rate of *P. pelagicus* due to fishing (F) is higher than its natural mortality rate (M), indicating an overfishing and overfished status. Similarly, the exploitation rate of *P. pelagicus* is E > 0.5, indicating that its utilization has exceeded the optimal level and that stocks are declining (overexploited). Under these conditions, it is necessary to reduce fishing efforts in both waters to maintain the stability of *P. pelagicus* stocks.

The overall exploitation rate (E) of *P. pelagicus* showed a high level of exploitation. The exploitation rate obtained indicates that exploitation of *P. pelagicus* was already above the optimum level (E = 0.5). Folding traps are selective fishing gear for BSC that tend to catch large crabs. However, this study found a high exploitation rate due to the large number of small crabs caught, which is thought to be because the fishing area is mainly in coastal areas near mangrove ecosystems. *P. pelagigus* uses mangrove ecosystems as nursery areas and foraging grounds, particularly during the juvenile phase of their life cycle. The overall exploitation rate (E) of *P. pelagicus* showed a high level of exploitation. The exploitation rate obtained indicates that exploitation of *P. pelagicus* was already above the optimum level (E = 0.5). Folding traps are selective fishing gear for BSC that tend to catch large crabs. However, this study found a high exploitation rate due to the large number of small crabs caught, which is thought to be because the fishing area is mainly in coastal areas near mangrove ecosystems. *P. pelagicus* uses mangrove ecosystems as nursery areas and foraging grounds, especially during the juvenile phase of its life cycle.

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