The sustainability of blue swimming crab (*Portunus pelagicus*) in the Java Sea, Indonesia: an approach to biological aspects and spawning potential

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Abstract. The sustainability of blue swimming crab (*Portunus pelagicus*) (BSC) in Java Sea, Indonesia, can be enhanced through strengthened stock-based management, optimization of fisihing effort, and improved monitoring of size and sex ratios to maintain healthy population dynamics. This research assessed the sustainability of BSC based on biological factors: carapace width size at first maturity (CWm), carapace width at first capture (CWc) and the spawning potential at six landing sites across the Java Sea (Cirebon, Pemalang, Pati, Rembang, Gresik, and Pamekasan) from 2019 to 2022. Data were collected daily by the APRI enumerator at each landing site from a total of 328,096 individuals. As shown by the data, the smallest CWc for the BSC was observed in crabs caught using a gillnet in Gresik, followed by gillnet-caught crabs in Cirebon and those caught with collapsible traps in Pamekasan. In the Java Sea, the average CWm was 94.78 mm, with the lowest CWm found in female crabs landed in Pemalang (83.82 mm) and the highest in Pamekasan (105.37 mm). The spawning potential ratio (SPR) varied from 16 to 42%. Furthermore, the selectivity curve for the BSC fishery at each landing site lies to the right of the standard maturity curve, indicating that most crabs mature and spawn before capture. Given the species' rapid growth and peak seasons (February-April and August-October), implementing limited fishing periods in heavily exploited areas is recommended to replenish broodstock and ensure long-term sustainability.

Key Words: blue swimming crab, CWc, CWm, fisheries management, SPR.

Introduction. The blue swimming crab or BSC (*Portunus pelagicus*) is widely distributed across the Indo-Pacific region, from the Indian Ocean to the eastern Pacific (Ernawati et al 2017), including the coastal waters of East and Southeast Asia (Lai et al 2010). The species particularly inhabit sheltered and shallow coastal areas (Williams 1982) with sandy or muddy substrates at a maximum 40 m depth in the ecosystems of mangroves, seagrass, coral reefs, and estuaries (Ng 1998; Novianingrum et al 2023). The BSC exhibits different habitat preferences throughout its life cycle (Hidayani et al 2015). Adults and juveniles live on the coastal seabed, while larvae and megalopa stages drift as plankton (Nontji 1987). BSC exhibits morphological adaptations to diverse aquatic environments (Hidayani et al 2015), females BSC typically migrating to higher salinity marine waters for spawning while juveniles and male adults inhabit coastal and estuarine areas (Potter et al 1983). In Indonesia, BSC is commonly found along the eastern coastline of Sumatra, the northern shoreline of Java, the southern and eastern regions of Kalimantan, the southeastern part of Sulawesi, and the southwestern area of Papua (Sumiono 1997; Ernawati et al 2017).

The BSC is considered a significant marine resource in Indonesia, especially in the Java Sea (MMAF 2012; Monterey Bay Aquarium Seafood Watch 2023) for its high economic value and demand in both local and global markets (Lai et al 2010; Anand &

Soundarapandian 2011; Johnston et al 2011; Sahoo et al 2011; Zairion et al 2015; Kembaren et al 2018; PDSPKP 2020; Soegianto et al 2022; FAO 2023). Many coastal communities catch the BSC to be sold, and the sales of this species make a substantial contribution to the country's fisheries export revenues (Fahmi et al 2015; Yanti et al 2022). The extensive exploitation and environmental changes raise concerns regarding the sustainability of the species (Sloan & Ugandhy 1994; Farhan & Lim 2010; Siry 2011; Fujaya et al 2014).

The northern Java and the eastern regions of Lampung have the largest BSC production (Afifah et al 2020). The production of BSC in the Java Sea fluctuates due to the exploitation (Wardiatno & Zairion 2011). Uncontrolled exploitation or overfishing is a threat to the environment and the crab resources, as indicated by a decrease in crab catch-per-trip and crab size (Zairion et al 2015; Ghofar et al 2018). Overfishing of juvenile crabs and berried females impact the reproduction rate that eventually results in population declines (Orensanz et al 1998). Habitat degradation (damages to mangroves and coral reefs) also impacts crucial breeding and nursery areas (Hutchison et al 2014; Zhang et al 2023). Climate change effects, like increasing sea temperatures and ocean acidification, further threatens crab populations and their habitats (Zhang et al 2019).

The biological characteristics of BSC can be analyzed from several metrics, such as size at maturity, size at captured, and spawning potential ratio (SPR) (Stearns 1989; Sukumaran & Neelakantan 1996; Hamid et al 2015; La Sara et al 2016). Understanding the population dynamics and spatial distribution of BSC is essential to prevent stock decline. This research analyzes the reproductive capacity of this fishery resource under current fishing pressures (Hordyk et al 2015), a method adopted by the Ministry of Marine Affairs and Fisheries (MMAF) since 2015 to assess stock status and fishery health (Ernawati et al 2017). Evaluating the SPR of BSC involves examining the percentage of mature individuals and their reproductive output to determine if the current exploitation rates support sufficient reproduction and sustainability (Prince et al 2015a). High fishing mortality (especially among breeding individuals) can significantly decrease the SPR and ultimately lead to population decreases (Goodyear 1993; Prince et al 2015b). Accordingly, assessing BSC sustainability in the Java Sea requires robust evaluations supported by improved management strategies (La Sara et al 2019).

This study aims to assess the sustainability of the BSC fishery in the Java Sea, Indonesia, by examining its biological characteristics and reproductive performance during 2019-2022. Specifically, the research evaluates population structure, size distribution, and maturity composition to determine key parameters such as size at first maturity (CWm) and size at capture (CWc). The spawning potential ratio (SPR) is used as a primary indicator to quantify reproductive capacity and infer the stock's sustainability status. Relationships among fishing intensity, catch per unit effort (CPUE), and population structure are analyzed to identify the effects of exploitation on stock productivity. The overall objective is to provide scientific evidence supporting adaptive, ecosystem-based management strategies to ensure the long-term sustainability of BSC. Effective management strategies that integrate scientific research, stakeholder engagement, and adaptive practices are crucial for the long-term sustainability of marine and fisheries resource. Such approaches seek to balance economic benefits with ecological integrity, ensuring that the blue swimming crab continues to support coastal livelihoods while contributing to Indonesia’s marine biodiversity.

Material and Method

Research area. The research was conducted in the Java Sea waters (Fisheries Management area or FMA 712) as the area with the largest BSC production (Afifah et al 2020). Six sampling points were selected based on data collection points identified by the Indonesian Blue Swimming Crab Association (APRI), including Cirebon, Pemalang, Pati, Rembang, Gresik, and Pamekasan (Figure 1).

The regional analysis using the statistical location quotient (LQ) method for sampling validity (Dunn 1960; Isserman 1977; Miller & Blair 2009) is as follows:

$$LQ = \frac{P_{ir}/Q_r}{R_{in}/S_n}$$

where: P_{ir} denotes the total production of BSC commodities (kg) in the research city, while Q_r represents the total marine capture fisheries production (kg) in the same city, r refers to the specific research location, R_{in} indicates the total production of BSC commodities (kg) within the corresponding province of Java, S_n represents marine capture fisheries production (kg) within the same province, n designates the province of Java that corresponds to the city where the research was conducted. A LQ value greater than one (LQ > 1) indicates that the research city holds a comparative advantage within its province.

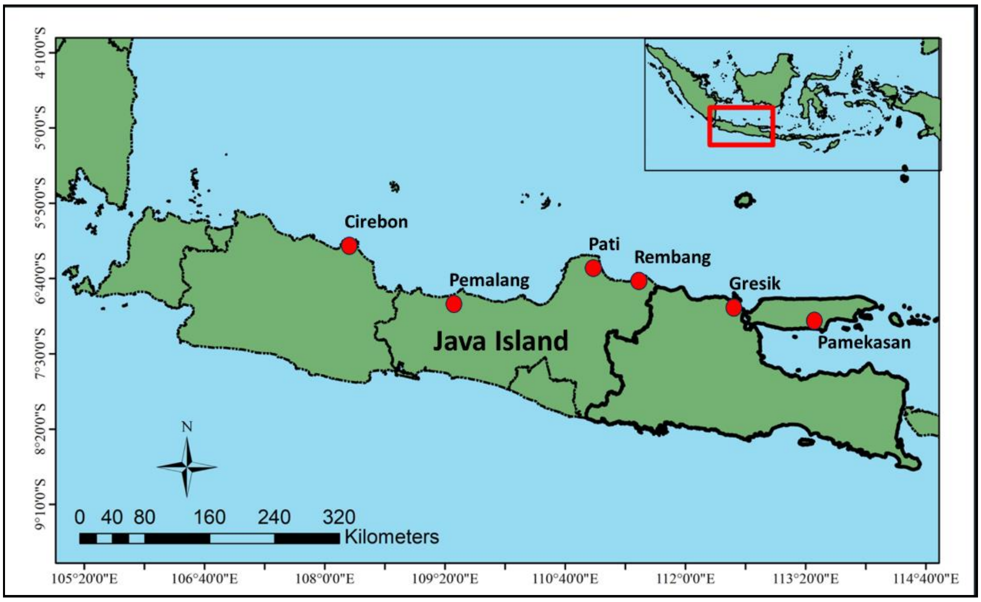

Figure 1. Map of sampling BSC in Java Sea waters (FMA 712), Indonesia.

Table 1 presents the LQ values across six research sites. Cirebon, Pemalang, Rembang, Gresik, and Pamekasan have LQ values greater than one (LQ > 1), indicating that the fishing of BSC is dominant and BSC is the major economic driver. On the other side, the LQ value of Pati is lower than one (LQ < 1), indicating that crabs are not the primary catch in the area. It can be inferred that Pati has the development potential to be included in the economic diversification strategy. Pati was included as a research site based on several considerations: (1) its relatively low fishing intensity provides a control site for comparison with the highest-LQ areas such as Cirebon, particularly in assessing exploitation impacts; (2) variation in LQ values across sites enhances the validity and robustness of ecosystem- and market-based management recommendations; (3) its coastal ecosystem, with river estuaries and muddy seabed substrates, supports the natural recruitment of BSC populations; and (4) its strategic role as a distribution and processing hub for surrounding catches strengthens its importance within the supply chain.

Table 1

Location quotient (LQ) of research location

Location	*Year*		
	2019	*2020*	*2021*
Cirebon	6.60	5.42	4.59
Pemalang	2.08	1.56	0.99
Pati	0.19	0.05	0.06
Rembang	1.43	1.12	1.80
Gresik	1.30	1.23	4.08
Pamekasan	2.76	2.50	3.47

***Research framework**.* This research assesses the sustainability of BSC in six Java Sea regions during 2019-2022, focusing on biological indicators, such as carapace width at first maturity (CWm), carapace width at first capture (CWc), and spawning potential ratio (SPR). These evaluations provide insights into stock status and long-term sustainability, ensuring that biological considerations inform management strategies and policies aimed at maintaining BSC populations in the Java Sea.

***Data collection**.* This research utilized secondary data from the Indonesian Blue Swimming Crab Association (APRI), specifically biological data from crab catches in six research locations within FMA 712, with sample details presented in Table 2. APRI, through its Fishery Improvement Project (FIP), develops eco-friendly fishing guidelines, implements initiatives to maintain crab population health and balance, and promotes sustainable industry management in Indonesia (APRI 2016). Data were collected by APRI-trained enumerators stationed in Cirebon, Pemalang, Pati, Rembang, Gresik, and Pamekasan, who monitored monthly crab catches and recorded biological parameters including carapace size, sex ratio, and gonad maturity.

Table 2

Total of BSC sample in research location (FMA 712, Java Sea)

Research location	*Sampling period*	*Total sample of BSC (ind.)*
Cirebon, West Java	2020-2022	36,400
Pemalang, Central Java	2019-2022	54,868
Pati, Central Java	2019-2022	62,081
Rembang, Central Java	2019-2022	52,581
Gresik, East Java	2019-2022	64,959
Pamekasan, East Java	2019-2022	57,207
Total		328,096

Enumerators are required to have a background or relevant work experience in fisheries sector, possess adequate social and communication skills with the local community at the data collection site, and demonstrate high mobility. Data were collected from 2019 to 2022 through mostly daily sampling, depending on the crab landing by fishermen. Samples were collected at each station point by the monthly catch.

Carapace width was measured with a ruler positioned between the lateral spines, while carapace length was measured with calipers from the dorsal to the ventral margins. Sample weight was recorded using a digital scale with 0.1 g precision. For female crabs, gonad maturity was assessed based on abdominal morphology (Kunsook et al 2014) and by gently pressing the junction between the carapace and abdomen. A whitish appearance indicated immature gonads, whereas yellow to orange coloration signified developed or mature gonads.

***Data analysis**.* Crab resource analysis was conducted using catch data and biological information from APRI, applying exploratory data analysis (EDA) techniques presented in graphs and tables. The analyses included:

a. Line graph to identify the CWm at sampling location;
b. Histogram to identify the CWc at sampling location and assess the distribution of CWc, thereby identifying the mode, smallest or largest data, and making a comparison with the minimum legal size stipulated by the government;
c. Pie chart to determine the SPR of BSC female that captured at sampling location.
d. The computation of two data, including size at the first mature using the carapace width (CWm) data followed. The determination of CWm was based on the correlation between the frequency of carapace width and the percentage of adult female crabs using the following logistic curve:

$$P = \frac{1}{(1 + \exp[-r(CW - CW_m)])}$$

where: CWm is a measure of maturity where 50% (CWm50) and 95% (CWm95) of the crab population are adults, r is the slope of the curve, and P is the proportion of adult female crabs (King 1995; Ervinia et al 2023).

The size at the first capture determines if the captured crab has reproduced at least once, which indicates the sustainability of crab resources. The carapace width at first capture (CWc) are also established by considering the correlation between carapace width and frequency. The specific formula based on the Spearman-Karber method with logistic curve as shown in the graph derived from equations as follows:

$$SL = \frac{1}{1 + \exp(S_1 - S_2 \times CW)}$$

where: SL is the logistic curve (probability of capture for given width class), CW is the carapace width, S1 and S2 are the logistic curve coefficients obtained through regression analysis. The intercept and slope of the regression are represented by S1 and S2, respectively. The value CWc (captures 50% of the range population) is determined by the ratio S1/S2 (Sparre & Venema 1998; Ervinia et al 2023).

The length-based spawning potential ratio (LB-SPR) was calculated in a web-based analysis using biological data of crabs and the following equation:

$$SPR = \frac{\sum(1 - \bar{L}_X)^{\left(\frac{M}{K\left[\left(\frac{F}{M}\right)+1\right]}\right)} \bar{L}_X^b}{\sum(1 - \bar{L}_X)^{M/K_{\bar{L}_X^b)}}} \; for \; x_m \leq x \leq 1$$

where: the SPR is the spawning potential ratio in an exploited population, which emphasizes the relationships between fishing mortality (F) to natural mortality (M) (F/M ratio), M/K ratio is the ratio of natural mortality rate (M) to von Bertalanffy growth coefficient (K), and two key life history ratios (carapace width (CWm)/asymptotic carapace width (CW∞)). The variables in the LB-SPR model consist of a) carapace width (CW); b) asymptotic length CW∞; c) the probability of capture at different carapace width typically assumed to be approximately 10%; d) $CWm_{50\%}$ - the size at which 50% of the population is gonadally mature, and e) $CWm_{95\%}$ - the size at which 95% of the population is gonadally mature (Prince et al 2015b).

The catch per unit effort (CPUE) represents the amount of catch obtained per standardized unit of fishing effort and serves as an indirect index of the relative abundance of exploited fish stocks. The calculation of CPUE aims to evaluate temporal changes in stock abundance and to support fisheries stock assessment and management (Gulland 1964).

$$CPUE = \frac{\text{Total Catch}}{\text{Total Fishing Effort}}$$

where: CPUE is Catch Per Unit Effort, total catch is kilograms (kg) of crabs, total fishing effort is total trip (day). Therefore, CPUE is determined by kg/trip or kg/day (Beverton & Holt 1993).

Results and Discussion

Sex composition*, *carapace width*, *and weight. From 2019 to 2022, the sex ratio of BSC varies significantly across different locations in the Java Sea (Table 3). Male crabs in Cirebon outnumbered females by 54%, with a ratio of 1.17:1. Gresik also confirmed male dominance with a ratio of 1.76:1 (64%). Conversely, Pemalang and Pamekasan recorded female dominance with ratios of 0.72:1 (58%) and 0.75:1 (57%), respectively. Meanwhile, Pati and Rembang had nearly equal ratios of 0.99:1 and 0.95:1, respectively, indicating a relatively equal number of males and females.

Table 3

Carapace width, weight, and sex composition of blue swimming crabs from sampling locations in Java Sea waters (2019-2022)

Location	*Sex*	*Sample size (ind.)*	*Sex ratio*	*GMR*	*Carapace width (mm)*			*Weight (gram)*		
					Min	*Max*	*Mean ± sd*	*Min*	*Max*	*Mean ± sd*
Cirebon	M	19,617	1.17:1	15%	46.7	165.0	113.7±13.4	17.1	631.0	107.7±44.2
	F	16,783			46.7	165.0	113.7±13.3	17.1	631.0	108.7±43.8
Pemalang	M	22,999	0.72:1	11%	61.8	175.0	115.0±15.9	22.1	339.7	108.5±48.9
	F	31,869			61.8	175.0	115.0±15.9	22.1	339.7	108.4±48.8
Pati	M	30,915	0.99:1	12%	76.0	169.9	111.9±12.4	22.4	651.6	104.6±44.9
	F	31,166			70.6	169.3	112.8±13.3	20.9	363.5	101.2±44.8
Rembang	M	25,645	0.95:1	18%	83.0	165.8	120.6±12.0	37.8	378.3	130.8±48.3
	F	26,936			82.8	170.8	119.7±13.4	34.4	410.3	120.7±49.7
Gresik	M	41,392	1.76:1	11%	64.8	188.7	111.4±10.3	18.6	339.1	100.0±32.7
	F	23,567			67.0	153.7	109.8±10.7	21.2	310.8	86.9±28.2
Pamekasan	M	24,598	0.75:1	6%	81.0	167.8	117.7±12.1	33.5	584.2	129.5±46.1
	F	32,609			64.5	166.0	119.1±11.7	33.7	332.1	121.1±37.3
Total		328,096	1.01:1							

Note: F is female; M is male; GMR is gonadal maturity ratio.

Variations in carapace width and weight of crabs were also observed across locations. The average carapace width of male and female crabs in Cirebon was nearly identical, at 113.7 mm with a slightly higher average weight in females (108.7 g) than males (107.7 g). In Pemalang, both sexes exhibited the same mean carapace width (115.0 mm) and nearly identical average weights (108.5 g for males and 108.4 g for females). In Pati, females had a slightly larger mean carapace width (112.8 mm) than males (111.9 mm), whereas males were heavier on average (104.6 g vs. 101.2 g). In Rembang, males surpassed females in both carapace width (120.6 mm vs. 119.7 mm) and weight (130.8 g vs. 120.7 g). In Gresik, males also exhibited a larger mean carapace width (111.4 mm vs. 109.8 mm) and a notably higher average weight (100.0 g vs. 86.9 g). In Pamekasan, although females had a slightly larger mean carapace width (119.1 mm vs. 117.7 mm), males were heavier (129.5 g vs. 121.1 g).

Based on the finding, BSC population in Pemalang and Pamekasan were predominantly female, Cirebon and Gresik were predominantly male, while those in Pati and Rembang had a nearly balanced ratio. On the other side, the significant differences in weight between males and females remained with exception in Pamekasan, where females exhibit a larger carapace width. Therefore, each area carries varrying local environmental conditions and ecological pressures, supporting the notion that BSC exhibit morphological adaptations to diverse aquatic environments (Hidayani et al 2015), particularly in response to migratory movements toward higher-salinity marine waters for spawning (Potter et al 1983).

The proportion of egg-laying female crabs (gonad maturity level 3) is an important biological indicator for assessing the potential for natural recruitment and fishing pressure on spawning females. As seen in Table 3, the proportion varies across the six research locations in WPP 712 during the 2019-2022 period, ranging from 6% to 18%. The highest value was recorded in Rembang at 18%, followed by Cirebon (15%), Pati (12%), Gresik, and Pemalang (each 11%). Pamekasan had the lowest proportion (6%), reflecting lower capture intensity of spawning females. These findings indicate that in several locations, a significant number of egg-bearing females are still caught in fishing gear.

Regarding sex ratios, the male dominance in Gresik (1.76:1) reduced the share of spawning females, whereas female predominance in Pemalang and Pamekasan increased their likelihood of being caught. Seasonal differences in sampling and spawning also contributed to variation among sites. Although SPR values and CWm and CWc in some areas, such as Pemalang and Gresik, suggest favorable reproductive potential, the capture of egg-bearing females reveals limited selectivity in current fishing practices.

Improper management disrupts the natural reproductive cycle and reduces the potential for recruitment in the wild. Thereby, the implementation of ecosystem-based management strategies, such as the Catch and Return 5 Minutes Movement as initiated by APRI is necessary. This movement encourages fishermen to release egg-bearing female crabs back into the sea in order to maintain the long-term sustainability of the crab population and supporting sustainability targets for exports.

Size at first maturity and at first captured. Table 4 and Figure 2 show the variations in the CWm across six locations in Java Sea waters from 2019 to 2022. In Grogol (Cirebon), BSC has a size at first maturity of 98.43 mm, with a size range of 118.98 mm between 2020 and 2022. In Pejarakan (Pemalang), the CWm of BCS is lower at 83.82 mm, but the size range extends to 120.31 mm from 2019 to 2022. Alasdowo-Keboromo-Margomulyo in Pati shows a CWm of 93.92 mm with a size range of 119.09 mm, while Gedungmulyo (Rembang) shows a CWm of 94.24 mm and a size range of 121.72 mm. In Pangkahwetan – Mengare (Gresik), BSC has a CWm of 92.91 mm and a size range of 115.31 mm. Pagagan - Candi in Pamekasan records the highest CWm at 105.37 mm with a size range of 118.01 mm. Local environmental conditions or population characteristics may influence the size at first maturity across different regions.

Table 4

Size at first maturity and capture in Java Sea waters and several Indonesian waters

Location	*FMA*	*CWm (mm)*	*CWc (mm)*	*Period*	*Reference*
Labuhan Maringgai, East Lampung	712	113.5	109.72	January-December 2012	Damora & Nurdin (2016)
Alastuwo, Pati	713	107	108	January 2012 - March 2013	Ernawati et al (2017)
Lasongko Bay, Central Buton	714	115	105	April 2013 - March 2014	Hamid et al (2017)
Jakarta Bay	717	98.91	105.45	December 2014 - March 2015	Jayawiguna et al (2017)
Aru Islands	718	119.9	133.4	January-April, June, August-November 2016	Kembaren & Surahman (2018)
Keboromo, Pati	712	107.21	113.89	November-December 2022	Novianingrum et al (2023)
Grogol, Cirebon	712	98.43	118.98	2020-2022	This study
Pejarakan, Pemalang	712	83.82	120.31	2019-2022	This study
Alasdowo-Keboromo-Margomulyo, Pati	712	93.92	119.09	2019-2022	This study
Gedungmulyo, Rembang	712	94.24	121.72	2019-2022	This study
Pangkahwetan - Mengare, Gresik	712	92.91	115.31	2019-2022	This study
Pagagan - Candi, Pamekasan	712	105.37	118.01	2019-2022	This study

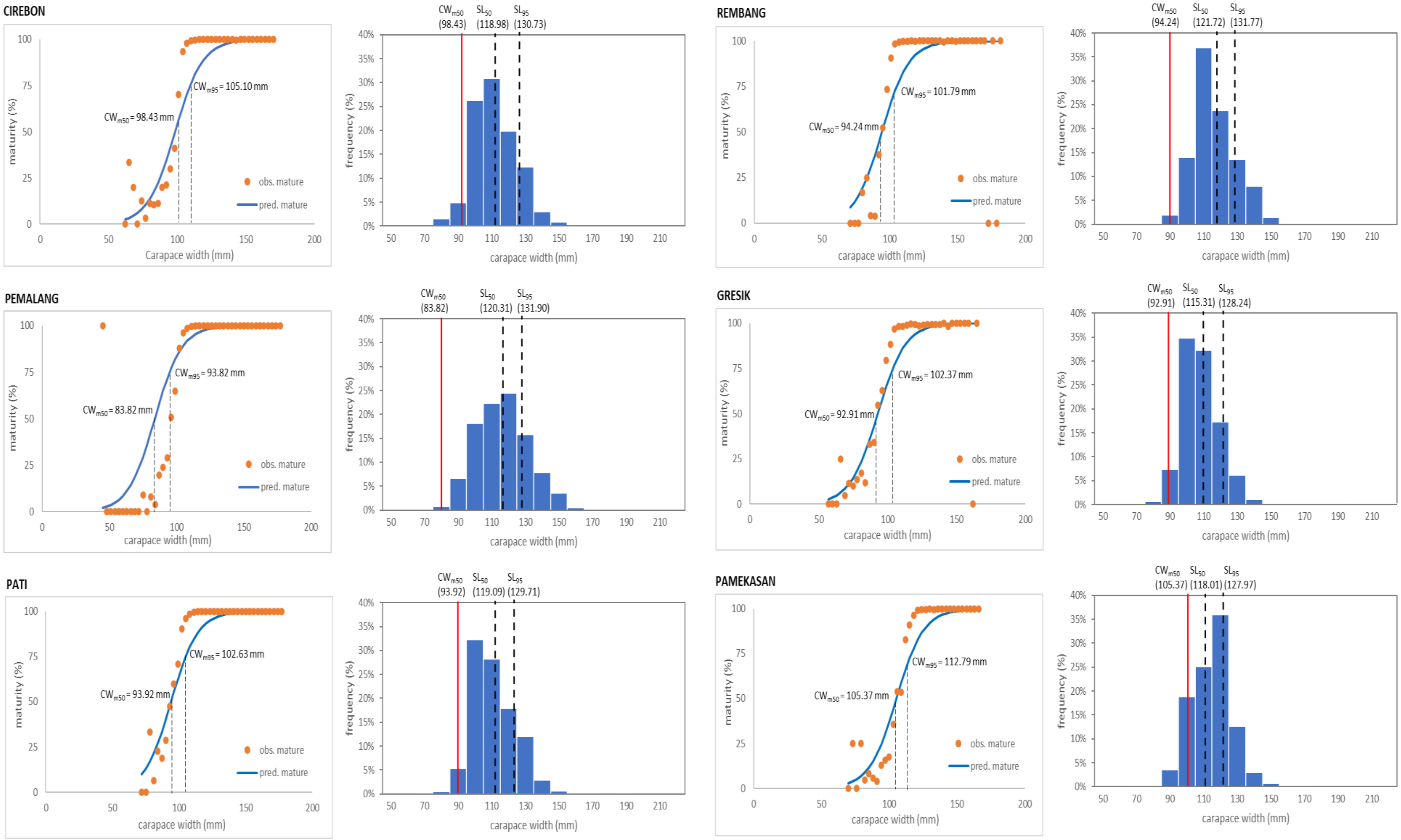

Figure 2. Logistic curve of carapace width at maturity and size-selectivity histogram of BSC in research locations (FMA 712, Java Sea).

Prior investigations have similarly undertaken studies across various geographical locales. Labuhan Maringgai in East Lampung showed a mean catchment width (CWm) of 113.5 mm (Damora & Nurdin 2016), whereas Alastuwo in Pati documented a CWm of 107 mm (Ernawati et al 2017). Lasongko Bay in Central Buton, exhibited a marginally elevated CWm of 115 mm (Hamid et al 2017). Whereas, Jakarta Bay recorded the minimum CWm of 98.91 mm (Jayawiguna et al 2017), while the Aru Islands presented the maximum value of 119.9 mm (Kembaren & Surahman 2018).

The CWc also varies significantly by location. In Grogol, Cirebon (118.98 mm) and Pejarakan, Pemalang (120.31 mm), CWc values were relatively high, indicating that crabs were generally captured after reaching maturity. In Labuhan Maringgai, the CWc was 109.72 mm, close to the length at first maturity (Damora & Nurdin 2016), while Alastuwo, Pati reported 108 mm (Ernawati et al 2017), suggesting a balanced capture size. Lasongko Bay recorded a slightly lower CWc of 105 mm (Hamid et al 2017), and Jakarta Bay 105.45 mm (Jayawiguna et al 2017), implying that crabs were harvested shortly after maturity. By contrast, the Aru Islands exhibited the highest CWc at 133.4 mm (Kembaren & Surahman 2018), indicating that crabs in this area had more time to mature before being caught.

Localized management strategies are necessary to ensure sustainable fishing practices, as the size and maturity of crabs at capture can significantly influence population dynamics of crab fisheries (Zairion et al 2015; Hisam et al 2018; Redjeki et al 2020). Understanding these variations is essential for developing effective conservation measures and ensuring the long-term viability of blue swimming crab populations (Cooper et al 2013).

Analysis of sex ratios, size at first gonadal maturity (CWm), and size at first capture (CWc) provides important insights into the sustainability of crab stocks across the six research sites. Table 3 shows variation in sex composition, with male dominance in Gresik and Cirebon, female dominance in Pemalang and Pamekasan, and relatively balanced ratios in Pati and Rembang. Such differences can affect reproductive dynamics, particularly when a high proportion of females are captured during spawning, thereby reducing natural recruitment potential.

Table 4 and Figure 2 show that the average size of captured crabs (CWc) is greater than the size at first gonadal maturity (CWm) at all sites. This biological significance indicates that most individuals had reached gonadal maturity before capture, implying that most crabs had the opportunity to spawn before capture. However, the size distribution in Table 3 indicates that juveniles are still being caught below the CWm, showing that fishing practices in some locations are not fully selective and may exert pressure on immature crabs. Such practices risk undermining the long-term sustainability of crab populations.

Although CWc > CWm indicates a positive trend from a reproductive perspective, the awareness among fishermen regarding regulations on fishing selectivity still needs to be improved. The minimum catch sizes and the prohibition on catching egg-bearing females are stipulated in MMAF Regulation No. 17/PERMEN-KP/2021. APRI, which implements the Fishery Improvement Project (FIP), initiated the GTK5menit (5-Minute Catch Return Movement) program. Fishermen are required to immediately release crabs caught measuring under 10 cm or egg-bearing females back into the sea. If egg-laying female crabs are caught in nets or traps, fishermen can place them in crab apartments provided by APRI to maintain the sustainability of crab stocks in WPP 712.

The balance between CWm and CWc is crucial in fisheries management. Harvesting crabs before they reach maturity reduces the number of breeding individuals, thereby weakening recruitment and threatening stock sustainability.

Spawning potential ratio (SPR). The SPR is a key indicator of the reproductive capacity and sustainability of BSC populations, representing the proportion of reproductive output in a fished population relative to its unfished state. Figure 3 presents the SPR across six locations between 2019 and 2022, with values ranging from 16 to 42%. In Rembang, the SPR in 2019 was 40%, that is above the precautionary threshold of 30%, reflecting a healthy and sustainable population. However, the ratio declined to

32% in 2020 and 33% in 2021, still above the critical threshold but indicating reduced reproductive capacity. By 2022, the SPR dropped further to 25%, approaching the critical limit of 20%, showing a significant decline and underscoring the need for timely management interventions to prevent stock depletion.

In Pemalang, the SPR has fluctuated, reflecting both signs of recovery and emerging risks. In 2019, the SPR reached 37%, indicating a healthy population above the 30% precautionary threshold. It then declined to 28% in 2020, falling below the threshold but remaining above the critical limit of 20%, suggesting increased risk to stock sustainability. A sharp recovery occurred in 2021, with the SPR rising to 42%, the highest recorded value, indicating strong reproductive capacity. However, by 2022 the ratio declined again to 32%. This downward trend highlights potential risks and the need for continued management to ensure the long-term sustainability of BSC stocks in Pemalang.

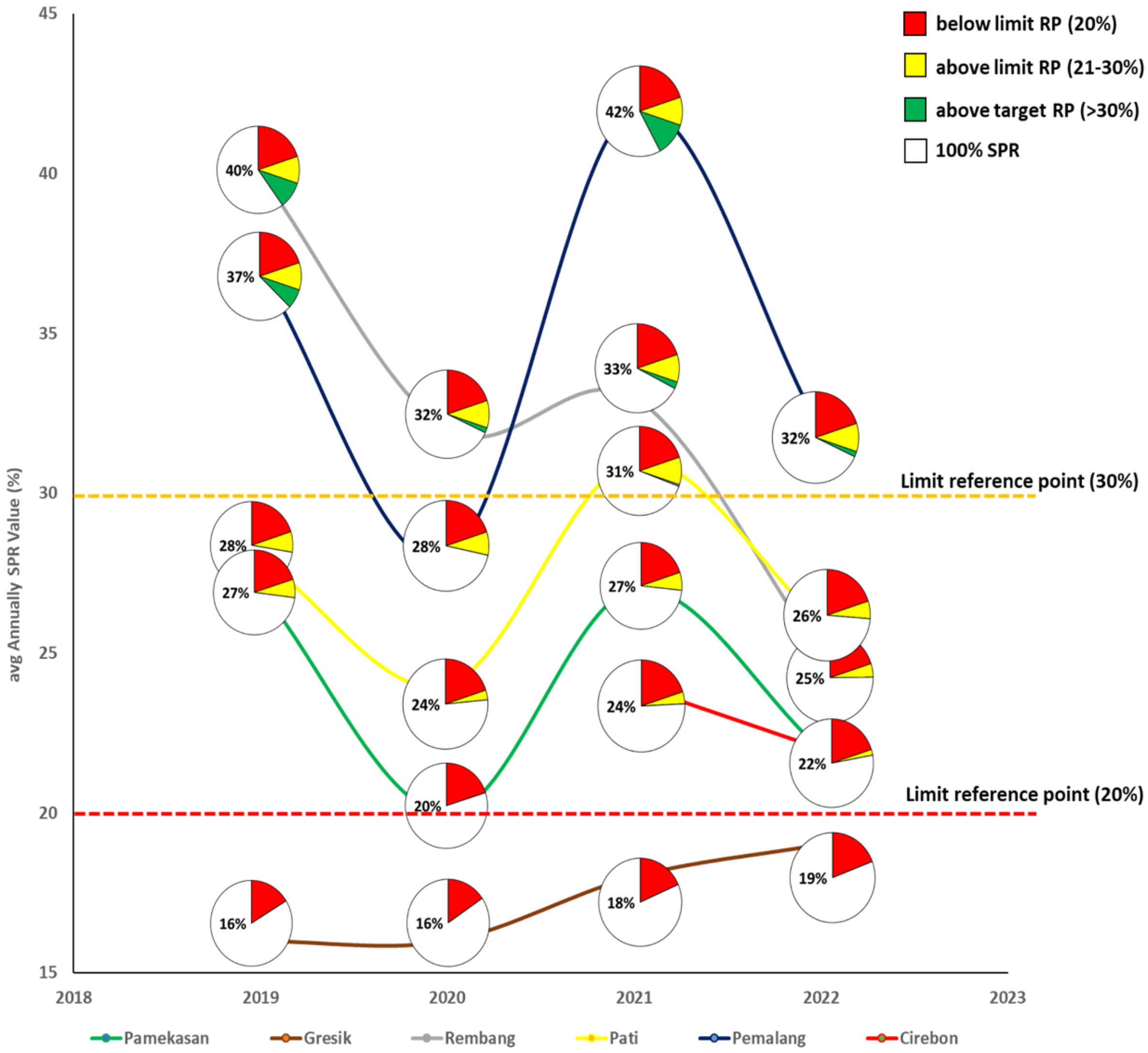

Figure 3. The SPR of blue swimming crabs in research location (FMA 712, Java Sea) during 2019-2022.

On average, the SPR and catch per unit effort (CPUE) values for swimming crabs in Pemalang were the highest among the six locations since the majority of fishermen fish at relatively distant fishing grounds from the coastline, ranging from 2 to 15 nautical miles. Fishing areas with more distant fishing grounds have lower fishing pressure, thereby increasing the chance of catching larger and heavier swimming crabs. These parameters influence the high CPUE values. Such distant fishing grounds experience lower fishing pressure, allowing crabs to reach larger sizes and heavier weights, which contributes to higher CPUE. Moreover, reduced fishing pressure provides crabs the opportunity to reach gonadal maturity and reproduce before capture, thereby supporting higher SPR values in Pemalang (28-42%).

In contrast, Pati exhibited marked fluctuations in SPR, reflecting alternating periods of recovery and decline. In 2019, the SPR was 28%, indicating moderate risk but still above the critical threshold of 20%. The value then declined to 24% in 2020, approaching the critical limit and signaling rising fishing pressure and stock vulnerability. A partial recovery occurred in 2021, with SPR rising to 31%, slightly above the 30% precautionary threshold. However, the ratio dropped again to 26% in 2022, once more below the threshold, underscoring the persistent vulnerability of crab stocks in Pati.

The SPR in Pamekasan also fluctuated between 2019 and 2022. In 2019, the SPR was 27%, approaching the critical limit of 30%, indicating a relatively healthy crab population. However, in 2020, the SPR dropped to 20%, reaching the critical limit. This significant decline indicated potential overfishing and raised concerns about the recovery of the blue swimming crab population. In 2021, the SPR increased to 27% which shows positive recovery before it declined again in 2022 to 22%. This situation urges for ongoing management efforts.

Similar trend was also confirmed in Cirebon and Gresik, where SPR values consistently approaching or remaining below the 20% critical threshold. In Cirebon, SPR was 24% in 2021 before declining to 22% in 2022, showing that recovery was short-lived and that the stock remains highly vulnerable. Seasonal variations in fishing contributed to these trends. In Gresik, SPR values stayed below 20% throughout 2019-2022, with 16% in 2019 and 2020, a slight rise to 18% in 2021, and 19% in 2022. The persistently low values are partly due to fishing grounds located only 0-10 nautical miles from shore, where spawning habitats for female crabs and juvenile concentrations are common. Such fishing practices increase the capture of immature individuals, thereby exerting additional pressure on stock recovery.

Overall, the SPR values varied across the research locations. Rembang and Pemalang showed higher SPR values. The SPR values of Gresik and Cirebon are consistently below or near the critical limit of 20%. The decline in SPR values in most locations below the critical limit of 30% urges more intensive fisheries management measures to maintain the long-term sustainability of BSC populations. Fishermen need to have greater awareness on this issue by not fishing in area close to the coastline, estuaries, or habitats where female BSC spawn.

Conclusions. This research provides critical insights for blue swimming crab management by emphasizing the importance of biological characteristics and spawning potential. Key parameters such as size at first maturity (CWm), size at first capture (CWc), and spawning potential ratio (SPR) across multiple locations are essential. The findings from six locations in FMA 712 during 2019-2022 indicate conditions that demand adaptive, ecosystem-based management. A nearly balanced sex ratio (1.01:1) suggests a stable population structure; however, the capture of egg-bearing females (6-18% of total females) and undersized crabs below CWm (83.82-105.37 mm) highlights the need for greater fishing selectivity. SPR values ranging from 15 to 42% (average 26%), although within the reference limit (20%), underscore the need to strengthen conservation measures. Meanwhile, catch per unit effort of 4-5 kg trip^{-1} aligns with the CPUE range in Ministerial Decree No. 83 of 2022, though it varies across locations.

Our findings show that long-term sustainability of blue swimming crab populations requires profound regulation on fishing practices, particularly during peak seasons and in regions experiencing excessive exploitation. Implementing blue swimming crab hatchery and restocking can help replenish broodstock and enhance sustainability. Combined with continuous monitoring and adaptive management, this approach can balance economic benefits with the ecological sustainability of blue swimming crab fisheries in the Java Sea (FMA 712). Such measures are crucial not only for maintaining crab populations but also for supporting local livelihoods and protecting Indonesia’s marine biodiversity.

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