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Ecosystem approach for blue swimming crab (*Portunus pelagicus*) sustainability in Bekasi District, West Java, Indonesia

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Abstract. *Yuliana E, Winata A, Setijorini LE, Yani DE, Hewindati YT, Djatmiko WA. 2024. Ecosystem approach for blue swimming crab (*Portunus pelagicus*) sustainability in Bekasi District, West Java, Indonesia. Biodiversitas 25: 4117-4126.* There is concern that the sustainability of blue swimming crab (BSC) (*Portunus pelagicus* Linnaeus 1758) resources is threatened by ever-increasing consumption. This has led to increased BSC fishing pressure, which can result in over exploitation. The study aims to analyze BSC sustainability based on the indicators of the ecosystem approach for fisheries management (EAFM) and to determine the follow-up in the form of management tactical steps. The study site was the waters of Segara Jaya Village, Taruma Jaya Sub-district, Bekasi District, West Java, Indonesia. The sampling location was the mudflats around the mangrove ecosystem. Data on BSC were collected from fishermen's catches; the crabs' carapace width (CW) and weight were measured, and their sex was identified. The fishermen data were collected from the entire population of Segara Jaya fishermen (40 people). We analyzed BSC sustainability using the CW-based stock assessment. The life-history parameters consisted of growth parameters, mortality, and exploitation rate estimated using the "TropFishR" package in RStudio; the rest used descriptive analysis. The results indicated that the BSC caught had an average CW of 7.25 cm (not compliant with the government policy) and an average weight of 29.24 g. There was overexploitation, with the exploitation rate value being 0.94 for males and 0.85 for females. The results of the water quality measurements were in accordance with seawater quality standards for marine biota. To properly educate fishermen, several counseling and motivational approaches are needed to build the fishermen's awareness. Regarding fishing techniques, educating fishermen to catch BSC larger than the minimum size set by the government (CW of >10 cm) is needed. Motivation-building to fishermen so that they are invested in conserving BSC resources is also needed in the socio-economy domain.

Keywords: BSC, EAFM, exploitation rate

INTRODUCTION

Blue swimming crabs (BSC) (*Portunus pelagicus* Linnaeus 1758) are one of the fisheries commodities produced by Indonesia (Hidayani et al. 2020; Maryani et al. 2023; Muzammil et al. 2021). BSC have high economic value and market demand both nationally and internationally (Muzammil et al. 2021). These conditions encourage an increase in fishing efforts for BSC (Hidayat and Bahtiar 2019; Baihaqi et al. 2021a, 2021b). It is feared that the increasing pressure of fishing efforts (Maryani et al. 2023) will threaten the sustainability of BSC resources and their habitat. Moreover, the increase in BSC fishing is not countered by knowledge and awareness about preserving of BSC resources. BSC fishing in all Indonesian waters is 63% of waters in overfishing conditions (Suman et al. 2020), and in northern coast of Java is heavily exploited (Widiyastuti and Tirtadanu 2024). To prevent damage to BSC resources in the short term, the Indonesian Government issued a policy through the Regulation of Minister of Marine Affairs and Fisheries (MMAF) of Republic Indonesia (RI) No.12 of 2020 concerning the management of lobsters (*Panulirus* spp.), mud crab (*Scylla* spp.), and BSC (*Portunus* spp.). In the Republic of Indonesia, this regulation includes restrictions on the size of these three types of biota that can be caught. Lobsters that are allowed to be caught must have a carapace length of >8 cm, mud crabs a carapace width (CW) of >15 cm, and BSC a CW of >10 cm (MMAF 2020). This policy is mandatory for all fisheries stakeholders in Indonesia.

The BSC population is spread across the east coast of Sumatra Island, the north coast of Java Island and the waters of Sulawesi Island (West Java Provincial Government 2022). Specifically for the north coast of West Java, crab fishing activities are concentrated in four districts, namely Cirebon, Indramayu, Karawang and Bekasi districts, with more than 19,000 fishermen (West Java Provincial Government 2022). This is because the

bottom of the waters in the Northern Region of West Java consists of sandy, muddy sand, sandy mud and mud substrates, which are suitable habitats for BSC. West Java Province BSC production in 2021 reached 12,638,322 kg (West Java Provincial Government 2022). Located on the north coast of West Java, Bekasi District waters is one of the BSC production centers (Baihaqi et al. 2021a), and is part of Indonesia Fisheries Management Area (IFMA) 712. Furthermore, the northern Java waters are one of the biggest BSC fishing grounds in Indonesia (Permatahati et al. 2020), and contributed ca. 40.57% of the total potential productivity of BSC in Indonesia. The estimated potential for BSC resources in all IFMA is 57,947 tons, while in IFMA 712 alone it is estimated to be 23,508 tons (MMAF 2022). The exploitation rate of BSC in IFMA 712 was over the optimum level in 2016 (Afifaha et al. 2020).

Segara Jaya Village, Bekasi District, is one of the coastal areas with BSC catching activities and is one of the BSC production centers in Bekasi District. The fishermen's catch in the village is dominated by BSC caught in the vicinity of the mangrove area. The sustainability of BSC resources is closely related to the quality of their habitat. The habitat of the BSC in Segara Jaya waters is the mudflats around the mangrove ecosystem. Good habitat quality will determine the sustainability of fish resources (Wang et al. 2023) including BSC. Local tourism activities are also continuing to develop in Segara Jaya, which are feared to impact the quality of the waters and the sustainability of BSC resources. Therefore, fisheries management that can guarantee the sustainability of BSC resources and the ecosystem is necessary.

Based on the conditions described, various options for managing stock status are needed (Naviah et al. 2022). Monitoring of BSC can be conducted in several ways, for example measuring the CW and weight relationship (Mehanna and Farouk 2021; Novianingrum et al. 2023; Suman et al. 2020), size structure (Novianingrum et al. 2023), and exploitation rate (Suman et al. 2020; Wagiyo et al. 2019). To estimate the biomass of different fish populations, it is necessary to know the length-weight relationships (LWRs) of the studied species. LWR is of great importance in fish stock assessments to estimate biomass of fish (Mehanna et al. 2018).

To date, the ideal form of fisheries management has not yet been found. The reasons for the currently weak management of fisheries are a lack of the biological data of the species caught and fishing data (Yuliana et al. 2019); the fishermen's low compliance with regulations (Yuliana et al. 2016), weak law enforcement and lack of assessment of small scale fisheries (Pita et al. 2019); the lack of a suitable model for fisheries management (Yuliana et al. 2019; Howell et al. 2021). Although many countries have formally committed to Ecosystem-Based Fisheries Management (EBFM), actual progress toward these goals has been slow (Howell et al. 2021). Apart from EBFM, it is also known as the ecosystem approach to fisheries management (EAFM), because the EAFM is based on a collaboratively established vision of desired future conditions that includes ecological, socioeconomic, and institutional views (Munawar and Hartig 2020)). However, this paper focuses on discussing EAFM because it is more suitable for the BSC management situation in Bekasi waters. Also, the EAFM approach aims to achieve synergy between the ecological and socioeconomic aspects (Martin 2023) in the context of sustainable fisheries management. Sustainable utilization of fish resources must improve the welfare of fishermen. Sustainable fisheries management encompasses four aspects of sustainability: ecological, socioeconomic, community, and institutional (Yuliana et al. 2019; Martin 2023).

The aims of this study were (i) to analyze BSC sustainability through size structure, CW and weight relationship, and exploitation rate; (ii) to analyze supporting factors for BSC sustainability using the EAFM indicators that include the habitat, fishing technique, institutional, social, and economic aspects; (iii) to determine tactical decisions in the management for BSC sustainability.

MATERIALS AND METHODS

Study area

The research location is the coast of Segara Jaya Village, Tarumajaya Sub-district, Bekasi District. The fishing area for the BSC is an estuary ecosystem in the eastern corner of Jakarta Bay. This area is a combination of many small river mouths from Tawar Estuary in the west and Sembilangan Estuary in the southeast corner, to Cikeas Canal Estuary and Blacan Estuary in the north, along with many other small rivers and unnamed waterways (Figure 1). The research location was determined based on the BSC-producing area in Bekasi District, one part of the north coast of Java. Based on the results of preliminary interviews, they captured BSC in muddy areas around the mangrove area. Therefore, the points of location for BSC data collection and water quality follow the mangrove area. The data collection points were determined based on the results of interviews with fishermen, which were taken by sampling for seven observation stations.

Procedures

Collecting data

The data collected included both primary and secondary sources (Table 1). BSC resource data included the length and weight of the BSC that were measured every day for three months (July, August, and September in 2022) by collecting a minimum sample of 50 BSC caught each day. The length of the BSC was measured using the crab's carapace width (CW). The BSCs that were the object of the study were taken from collectors. BSCs fishermen sell their catch to collectors, so BSCs with various sizes are very complete at the collectors. From the collected BSCs, at least 50 samples were taken daily for three months. Sampling days were not carried out per day but at least once every two weeks. From the sampled BSCs, the carapace length and weight were measured. Sex identification was also carried out to determine the comparison between male and female BSCs.

Table 1. Data requirements for each EAFM domain

Indicator	Operational definition	Data Required	Data type
BSC resources: Size structure Exploitation rate Correlation between length and weight	Fish resources indicators measure the sustainability of fish resources through the structure of fish size, exploitation rate, and length-weight relationship	CW CW CW and weight	Primary Primary Primary
Habitat: Water quality	Habitat indicators measure the quality of the environment or habitat where fish resources live namely water quality	pH, temperature, total dissolved solids (TDS), salinity	Primary
Fishing technique: Fishing selectiveness	Fishing technique indicators measure the selectivity of fishing gear towards environmentally friendly fishing gear	The fishing gear used by fishermen to catch BSC is identified. The gear is analyzed to determine whether it is environmentally friendly. The gear is also analyzed to determine whether it can select the size of BSC that is allowed to be caught.	Primary
Institutional: The fishermen's perception of the rules	Institutional domain measure the contribution of institutional aspects (including the rules) to fisheries management. In this case, the institutional domain measures fishermen's perceptions of the rules applied in fisheries management. This perception measurement is needed to determine the extent to which the rules from the authorities reach fishermen and are well understood by fishermen.	Fishermen's perception. Data on fishermen's perceptions were obtained by distributing questionnaires (Likert scale) containing questions about the completeness of the rules applied and the mechanism for implementing regulations related to BSC.	Primary
Socio-economy The fishermen's perception of BSC resources and economic situation	Social indicators measure social aspects that occur after implementing fisheries management, namely fishermen's perception of BSC resources. And, measure economic aspects that occur after implementing fisheries management. The economic aspect measures the level of fishermen's welfare. However, the level of welfare cannot be measured directly; indirect measurements are needed. One indirect measurement is conducting a survey on goods ownership. Ownership of particular goods by fishermen indicates the level of fishermen's welfare.	Fishermen's perception. Data on fishermen's perceptions were obtained by distributing questionnaires (Likert scale) containing questions about the sustainability of fish resources, especially BSC. and the economic situation. The questionnaire also asked about fishermen's asset ownership	Primary

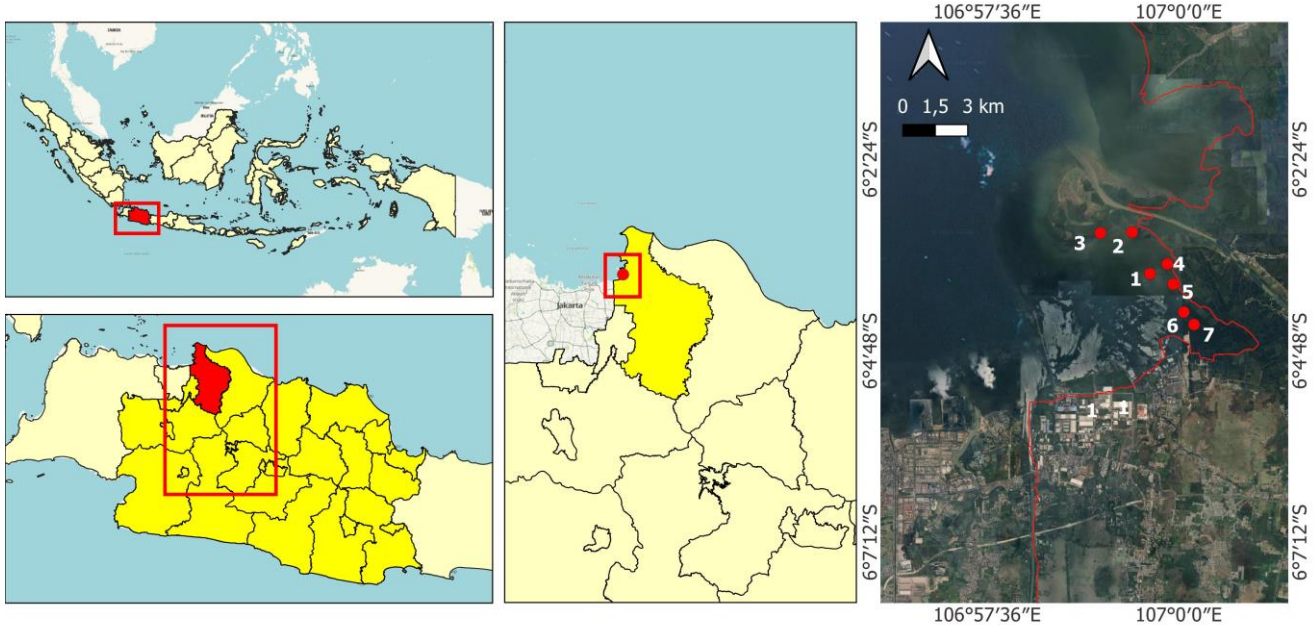

Figure 1. The study site (Segara Jaya coast, Bekasi District), the BSC catching area, and the water quality sampling points. Note: 1. Station I; 2. Station II; 3. Station III; 4. Station IV; 5. Station V; 6. Station VI; 7. Station VII

Water quality data collection in the habitat domain was carried out at seven observation stations (Table 2), whose conditions were considered to represent the condition of Segara Jaya waters. The water quality standard adhered to the guidelines for marine biota (Ministry of Environment Republic of Indonesia No. 51 of 2004).

The socioeconomic data were collected from respondents, specifically from 40 fishermen who caught the BSC. Based on the results of interviews with the head of the fishermen's group, there are 100 BSC fishermen in Segara Jaya Village. The research respondents were identical to the population, comprising 40 fishermen.

Data analysis

The data analysis referred to the study objectives, first descriptively, then the tactical decisions on BSC management were determined (Table 3). Data analysis was performed on all the EAFM indicators used to analyze the existing status.

Data on the length-CW, growth pattern, and condition factor (CF) play an essential role in fisheries assessment (Jisr et al. 2018; Dinh et al. 2022). The CW and weight relationship is an important parameters (Jisr et al. 2018; Kumar et al. 2022) was calculated based on the following formulas:

$W = a.L^b$

Where:
W=the fish's weight (g)
L=the fish's total length (mm)
a=a constant
b=the estimator of the fish growth pattern. The values of a and b are obtained from a simple linear equation.

$Y = b_0 + b_1X$

Where:
Y= as Log W and X as Log L

The constant b_1 and b_0 can be calculated using the following equation.

$$b_1 = \frac{\sum_{i=1}^{n} x_i y_i - \frac{1}{n}\sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2} \text{ ; and } b_0 = \bar{y} - b_1\bar{x}$$

We assessed the fish stock using the length-based stock assessment. The life-history parameters consist of growth parameters (asymptotic length/L_∞, growth coefficient/k, the theoretical age when the length is 0/t_0), mortality (natural mortality/M and fishing mortality/F), exploitation rate (E) estimated using the "TropFishR" package in Rstudio (Mildenberger et al. 2018) following the von Bertalanffy growth model: $\boldsymbol{Lt = L\infty\left[1 - e^{-k(t-t_0)}\right]}$.

RESULTS AND DISCUSSION

BSC resources

The BSC that is the object of research is the result of catches using bare hands. Data were collected for 3,892 ind of BSC (2,109 males and 1,783 females) with an average carapace width of 7.25 cm and an average weight of 29.24 g (Table 4), with the CW range being 4-12 cm. This range is smaller than the results of previous research in Pati, Central Java, Indonesia which were 7-16.8 cm (Novianingrum et al. 2023); Bintan, Riau Islands, Indonesia at 10.2-18.7 cm (Muzammil et al. 2021). However, the findings in this study are almost the same as research results in 2019 in Jakarta Bay, with measurements of 5.1-13.4 cm (Wagiyo et al. 2019).

Table 2. Water quality data sampling points

Location	Coordinate Point	
	South	East
Station I	6°03'50.5"	106°59'38.6"
Station II	6°03'17.5"	106°59'24.1"
Station III	6°03'20.9"	106°59'01.6"
Station IV	6°03'42.1"	106°59'51.2"
Station V	6°03'56.6"	106°59'55.7"
Station VI	6°04'14.9"	107°00'01.5"
Station VII	6°04'27.0"	107°00'11.3"

Table 3. Data analysis

Study objective	Data Analysis	Output
Analyzing the BSC sustainability includes size structure, CW and weight relationship, and exploitation rate	• Descriptive analysis • The bsc's cw and weight relationship • Measuring the bsc exploitation rate using the length-based stock assessment includes growth and mortality parameters	The existing BSC resource status for sustainability
Analyze supporting factors for BSC sustainability using the EAFM indicators that include the habitat, fishing technology, institutional, social, and economic aspects	• Water quality, is analyzed by comparing field data with water quality standards for marine biota specified in the Ministry of Environment Republic of Indonesia No. 51 of 2004 • Analysis of fishermen's perceptions using a Likert scale and calculating the percentage of each component	Status of supporting factors for BSC sustainability
Determining and establishing tactical decisions for blue swimming crab management	Tactical decision management for indicators that are in poor condition. From each domain, indicators with low achievement need to be determined by tactical decisions that can improve their achievement. For domains with high indicator achievement, tactical decisions are not needed.	Tactical decisions on the blue swimming crab management

The frequency of BSC caught at all class intervals was dominated by males, except at the interval of 4.7-5.3 cm; 5.4-6.0 cm; and 8.2-8.8 cm (Figure 2). Based on the average CW data (7.25 cm), the size of the BSC caught was below the size permitted by the Indonesian government, namely >10 cm (MMAF 2020). Based on regulations from the Indonesian government through the Regulation of MMAF of RI No.12 of 2020, 98% of BSC were not suitable for catching at the research location for males (2,070 ind from 2,109 ind), and for females 97% (1,727 ind from 1,783 ind). If based on the length at first maturity (L_m) with a value of 6.9 cm (Wagiyo et al. 2019), then the BSC that was not suitable for catching was 26.5% for males (560 ind from 2109 ind), and for females it was 39.2% (699 ind from 1783 ind). Fishermen at the research location mostly used their hands to catch crab, so they could not filter the size of BSC based on what was worth catching. As a result, all sizes of BSC caught were included in the catch.

On the other hand, fishermen are very dependent on BSC catches as a source of livelihood. This dependence of fishermen creates a bias towards the strict implementation of government regulations. If the rules are strictly enforced, the victims will be small-scale fishermen who are at the lowest economic level. The conflict between fishermen's interests in fish resources and complying with government regulations is the main issue that must be resolved in Indonesian small-scale fisheries (Halim et al. 2020). This adds complexity to managing BSC resources.

The calculation of the relationship between carapace width (CW) and weight of the BSC, with a 95% confidence interval, resulted in b=2.21 (male) and b=2.23 (female) (Figures 3 and 4). The two b coefficient values show that male and female BSC have the same growth pattern, a negative allometric, meaning that the increase in body length is more dominant than the increase in weight. This indicates that the BSC were not plump. Compared with the results of previous research in other locations, namely in Pamekasan waters (East Java), the BSC growth pattern is positive allometric (Maryani et al. 2023). The results of this study differ from this due to several factors, for example, food availability, habitat conditions, and other environmental pressures.

Related to the exploitation, assessment of fish stock status is generally required for fisheries management (Al-Mamun et al. 2021). The calculation and research results of each population parameter indicated that the BSC exploitation rate was higher than 0.5 (Table 5). A sustainable exploitation rate (E) in certain waters was at a value of E <0.5 with a maximum value of E=0.5. The exploitation rate for male BSC was 0.94 and 0.85 for females, indicating that there was over-exploitation. Compared with the results of previous research, the E value for BSC in the Western Visayan Sea research location, Philippines was 0.68 (Mesa et al. 2018). Over-exploitation is one of the pressures on the sustainability of fish resources and the environment. One form of environmental pressure in aquatic environments is the over-exploitation of target fish communities (Yuliana et al. 2022).

From the BSC resource domain, the average length of the BSC was 7.25 cm. This was a violation of the rules for catching BSC, which state that only BSC with a carapace length of more than 10 cm can be caught (MMAF 2020). Fishermen catch BSC with their bare hands in shallow areas. It is suspected that the fishing location for BSC (Figure 1) is a spawning and nursery location, explaining the relatively small size of the BSC caught, which is below the permissible size for catching (Baihaqi et al. 2021a, 2021b). Avoiding catching BSC below the specified size is mandatory because it helps maintain the sustainability of BSC resources. Fish diversity and sustainability are important indicators of fish stock security from which an acceptable level of fishing can be set (Yuliana et al. 2019). The absence of proper management in utilizing BSC resources results in the depletion of stocks and affects the fishermen's economy (Imadiah et al. 2023).

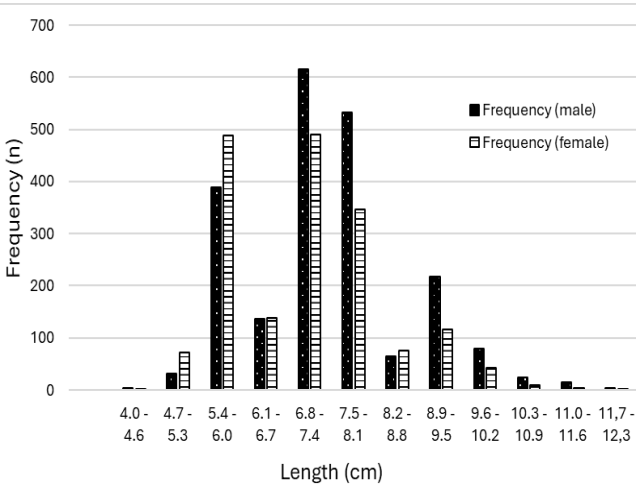

Figure 2. The blue swimming crab CW frequency distribution

Table 4. Numbers, carapace width and body weight of BSC sampled during study

Month	Number of Individuals	Male (heads)	Female (heads)	Average CW (cm)	Average weight (g)
I	1,095	593	502	7.14	27.99
II	1,448	796	652	7.10	27.91
III	1,349	720	629	7.50	31.83
Total	3,892	2,109	1,783	-	-

Table 5. BSC population parameters life-history parameters and exploitation rate at the study site

Population Parameter	Male	Female
Growth		
Growth coefficient (k)	0.95 per year	0.28 per year
Theoretical age when the BSC length is 0 (t_0)	-0.18 year	-0.66 year
Infinity BSC length asymptotic (L_∞)	23.18 cm	20.54 cm
Growth pattern	a=0.34; b=2.21 (negative allometric; b<3)	a=0.48; b=2.23 (negative allometric; b<3)
Mortality		
Natural mortality (M)	1.53 per year	0.71 per year
Fishing mortality (F)	22.21 per year	4.15 per year
Total mortality (Z)	23.74 per year	4.87 per year
Exploitation rate (E)	0.94	0.85

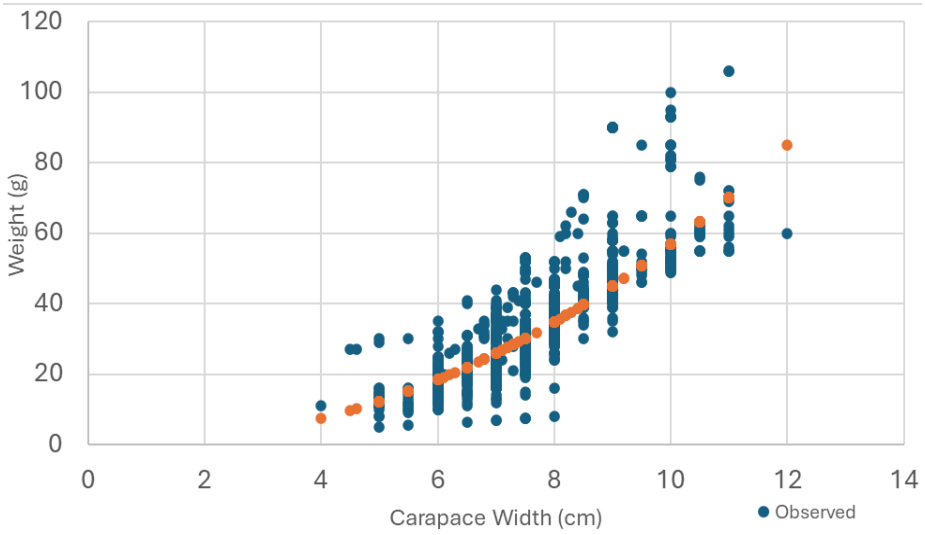

Figure 3. The correlation between CW and weight in male blue swimming crabs ($W=0.34L^{2.21}$). Notes: a (a constant)=0.34; b (the estimator of the fish growth pattern)=2.21; var (variance)=0.05; Wr (average of BSC weight)=102.39 g)

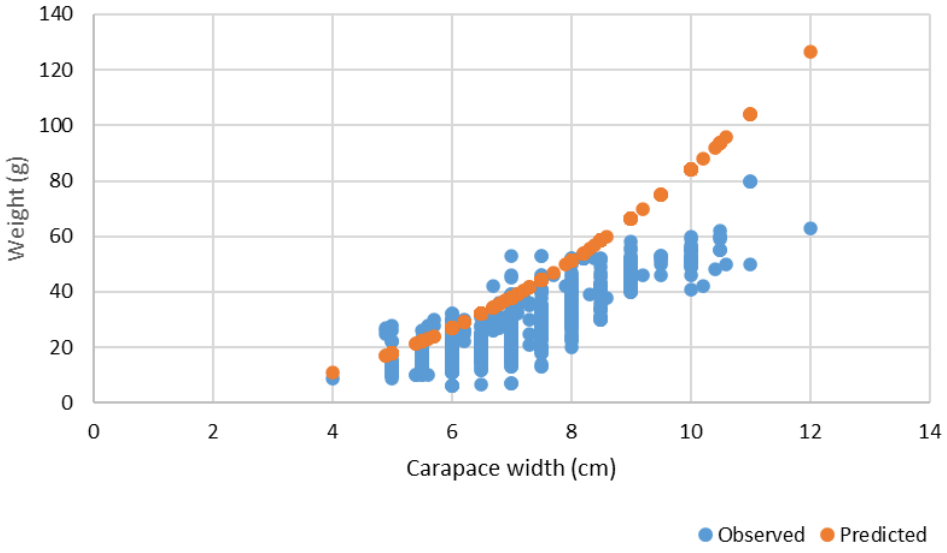

Figure 4. The correlation between CW and weight in female blue swimming crabs. Notes: a (a constant)=0.48; b (the estimator of the fish growth pattern)=2.23; var (variance)=0.05; Wr (average of BSC weight)=155.54 g)

Table 6. Sea water quality at the study site

Location	pH	Temperature (°C)	TDS (ppm)	Salinity (‰)
Station I	7.60	29.30	5,901	15
Station II	7.42	31.00	3,850	3
Station III	7.41	31.30	8,640	9
Station IV	7.60	30.40	20,000	10
Station V	7.67	32.30	20,000	10
Station VI	7.71	31.70	20,000	9
Station VII	7.86	31.50	20,000	14
Average	7.61	31.07	14,056	10

The growth of male and female BSC had a negative allometric pattern. Many factors influence the growth pattern of fish, including the BSC, such as differences in age, sex, gonadal development, and food availability in the environment (Mehanna et al. 2018). In this case, the BSC at the study site were considered to be less plump due to the reduced availability of food, because the study site had many uses other than fisheries, such as tourism). Tourism activities are thought to affect habitat health and the availability of food for BSC.

The exploitation rate of male BSC reached 0.94 and 0.85 for female BSC, indicating that Segara Jaya had reached a state of overfishing of BSC. The maximum limit for the rate of exploitation is 0.5; a rate exceeding 0.5 indicates over-exploitation. This issue needs attention from government agencies and the community so that overfishing does not continue.

Habitat

The habitat domain is crucial and considered one of the key factors in the successful management of BSC. The habitat domain in this study consisted of two indicators: water quality and mangrove ecosystems. The water quality standard used refers to the Decree of the State Minister for the Environment No. 51 of 2004 concerning Seawater Quality Standards for Marine Biota. It was found that the water quality indicators (Table 6) were in accordance with this decree. However, the water salinity at the study site of 10‰ (Table 6) is not suitable for BSC, because they are often found in habitats with substrates of dusty mud, high salinity and organic matter (Maryani et al. 2023).

From the habitat domain, the seawater quality indicators measured in this study were in accordance with the Decree of the Minister of State for the Environment No. 51 of 2004 concerning Seawater Quality Standards for Marine Biota. This needs to be maintained so that marine biota including the BSC can thrive. The habitat of BSC is the coastal area, from the intertidal area to deeper waters. Coastal areas vegetated with coastal forests or mangroves are important ecosystems for supporting the lives of BSC offspring (Radifa et al. 2020).

Fishing technique

BSC at the study site were caught using folding traps, gill nets, and bare hands (the local term is gogo). These fishing techniques are environmentally friendly because they do involve the use of tools or materials that damage the environment. However, each method has weaknesses that could threaten the BSC sustainability. Folding traps, for example, need to be evaluated because they can trap (catch) BSC in large numbers and various sizes. If BSC capture with traps is not limited, it is feared that it could cause the degradation of BSC resources.

The BSC data discussed in this article are from those caught using bare hands. In this case, fishing for BSC is done at low tide in shallow water, allowing fishermen to squat without submerging their noses, so they can still breathe freely. The fishermen are unable to see the BSC but can feel them using their hands or feet. This technique, known as the gogo method, also requires evaluation because it often tends to ignore the size of the BSC. As a result, the size of the BSC identified in this study (4-12 cm) is relatively smaller compared to previous research in Pati, Central Java, 7-16.8 cm (Novianingrum et al. 2023); Bintan, Riau Islands, Indonesia 10.2-18.7 cm (Muzammil et al. 2021); Jakarta Bay 5.1-13.4 cm (Wagiyo et al. 2019).

The BSC fishing techniques used by fishermen were classified as environmentally friendly because they used gill nets, folding traps, and bare hands. The operation of environmentally friendly BSC fishing techniques is a factor in maintaining the sustainability of BSC resources. The fishing area for BSC is strongly influenced by the ability of the fleet to carry out fishing operations; the larger the fishing vessel, the farther the fishing grounds will be (Baihaqi et al. 2021a). However, in this study, the BSC studied were those caught with bare hands.

Institutions

The institutional domain of EAFM measures the completeness of the rules and compliance with the principles of responsible fisheries (Gazali 2019). In this study, the measurement of the institutional domain is limited to public perception of the rules implemented by authorities. This is to measure the extent to which the authorities' rules can be understood by the public and implemented and whether the rules implemented include the principles of responsible fisheries.

Results of the analysis of fishermen's perceptions about the rules applied in BSC management, indicated that the majority of respondents (96.67%) agreed that it is the fishermen's responsibility toward the marine environment to comply with existing regulations. The rules implemented are government regulations and local fishermen's agreements. A majority of the fishermen (73.33%) agreed that they need to be involved in creating BSC management rules.

Most fishermen (62.50%) understood that there are rules that must be followed to preserve BSC in Indonesia, especially at the study site. However, only 50.00% of the fishermen knew and understood the size regulations for BSC that may be caught. It means that the authorities' rules only reach 50% of respondents, the remaining 50% do not know about the existence of rules regarding the size of the BSC that can be caught. There is 46.67% of fishermen were unaware of the existence of these rules. These findings showed that fishermen must be regularly informed of regulations related to the size of BSC that can be caught

so that more fishermen understand and are aware of these regulations.

This is linked to the frequency of extensions carried out by the government or local officers to educate fishing communities about BSC regulations. The survey results showed that only 50.00% of the fishermen had received information from extensions while the other 50.00% had not. Successful management of ecological aspects in fisheries is closely tied to the institutional domain, which involves aspects of governance such as stakeholders, legal components (formal and informal), and processes.

Socio-economy

The socioeconomic domain pertains to the fishermen's perceptions of BSC resource preservation and their economic situation. The results of the fishermen's perception analysis showed that 50% of the fishermen were aware of the decrease in size of the BSC they caught, while 33.33% said they were unaware; 63.33% of the fishermen agreed that the catches were declining. The fishermen's knowledge about conserving BSC resources was lacking because 53.33% of the fishermen were unaware that BSC resources had to be conserved for future generations. However, 70% of the fishermen agreed that the mangroves should be preserved to become a healthy habitat for the growth and development of BSC.

Regarding asset ownership, most of the fishermen already had cell phones and television sets, while only 50% of the fishermen owned motorcycles. It means that more than 50% of respondents can meet primary and secondary needs. Fulfilling primary and secondary needs can indicate that the welfare of more than 50% of BSC fishermen is quite high. So, it can be concluded that crab fishing is an interesting job. Further, 63.33% of the fishermen desired another job to supplement their income in between catching BSC. Efforts included finding information about other jobs and seeking venture capital. This is linked to the relatively profitable nature of the BSC fishing business for fishermen (Azis et al. 2022).

Tactical decisions

The discussion of research results in the domains of BSC resources, habitat, fishing techniques, institutional, social, and economic factors, along with tactical decisions for BSC management, is presented in Table 7. Tactical decisions are determined based on the findings to guide improvements in management.

Table 7. Tactical decision management for the BSC

Domain and indicator	Findings	Tactical decision
BSC resources Exploitation rate	Male E=0.94 Female E=0.85	Regulate the maximum catching effort Encourage the fishers to catch BSC above the size regulated by the government (>10 cm), and modifying fishing gear to increase the selectivity to 12 cm CW (Widiyastuti and Tirtadanu 2024)
Habitat		
Water quality	pH=7.61; temperature=31.07°C; TDS=14,056 ppm; salinity=10‰ (in line with the seawater quality for marine biota standard, Decree of the Minister of Environment No. 51 of 2004).	Maintaining the current water quality and trying to improve it.
Fishing techniques	The fishing gear used were nets, traps, and bare hands. Traps need to be evaluated because they can catch a large number of crabs of various sizes	Educate fishermen to catch BSC larger than the minimum size set by the government. The selection of fishing gear should be following the government policy regarding the minimum size of BSC allowed to be caught
Institutions	• The fishermen were rarely involved in the establishment of BSC management regulations • The fishermen did not receive adequate extensions on the BSC management	The government and authorities should involve fishermen in establishing regulations regarding BSC management and increase the intensity of extensions to the fishermen
Socio-economy	• 50% of the fishermen were aware that the size of the BSC caught was dwindling; 63.33% of the fishermen were aware that the number of crabs caught has been decreasing • A majority of the fishermen owned cell phones and television sets, while only 50% owned motorcycles. Ownership of these items is assumed to be one indicator of fishermen's level of welfare. If fishermen have these items, they are considered to be able to meet their basic needs. The study's results showed that more than 50% of respondents have these items, meaning that more than 50% of respondents can meet primary and secondary needs.	Providing extensions and motivation-building to fishermen so that they are invested in conserving BSC resources

In conclusion to the indicator of the BSC size structure, this BSC resource is not sustainable because (i) the average carapace width of the BSC caught (7.5 cm) does not comply with Indonesian government regulations through the Regulation of MMAF of RI No.12 of 2020, namely the size of the BSC. What can be caught is a carapace width of >10 cm; (ii) the CW relationship indicator shows that BSC has a negative allometric growth pattern, meaning that the increase in body length is more dominant than the increase in weight; (iii) the exploitation rate shows that Segara Jaya had reached a state of overfishing of BSC due to the exploitation rate of male BSC reaching 0.94 and 0.85 for female BSC.

The role of supporting factors based on EAFM indicators is (i) habitat domain, the seawater quality indicators measured in this study were in accordance with the Decree of the Minister of State for the Environment No. 51 of 2004 concerning Seawater Quality Standards for Marine Biota; (ii) fishing technique domain, the BSC fishing technique used by fishermen was classified as environmentally friendly because they used gill nets, folding traps, and bare hands, but the fishing gear used can catch small crabs of <10 cm; (iii) institutional domain, fishermen's perceptions of the BSC management rules showed that the majority of respondents (96.67%) agreed or strongly agreed that it is the fishermen's responsibility toward the marine environment to comply with existing regulations; socioeconomic domain, fishermen's perception analysis showed that 50% of the fishermen were aware that the size of the BSC they caught was shrinking and fishermen desired another job to supplement their income in between catching BSC.

The most important tactical decision related to the results of the assessment using EAFM indicators is to educate fishermen to catch BSC larger than the minimum size set by the government. The selection of fishing gear should comply with government policy regarding the minimum size of BSC allowed to be caught, and the government and authorities should involve fishermen in establishing regulations regarding BSC management and increase the frequency of extensions to the fishermen.

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