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A MARINE PROTECTED AREA DESIGN TO PROTECT THE BLUE SWIMMING CRAB POPULATION IN SALEMO ISLAND, SPERMONDE ARCHIPELAGO

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ABSTRACT

Blue swimming crab fishery in Salemo Island, Spermonde Archipelago, indicates overfishing. To ensure the sustainability of the blue swimming crab fishery, conservation effort through fishing prohibition needs to enforce. This research aimed to design a reservation area to protect the blue swimming crab resources. The study was conducted from May to July 2015. Creating a reserved area requires information on female berried crabs and larval abundance as the basic assumption that places containing the two information are the spawning ground. Information on female berried crabs in Salemo Island is readily available in the literature, while information on larval abundance must be obtained through this study before designing the reservation. Larvae of the blue swimming crabs were sampled using larval nets. Sampling was performed in three habitats: seagrass beds, coral reefs, and mangroves (estuaries). Differences between habitat's larval abundance were analyzed using a Student T-test, while the reservation area was designed using Marxan Software. Total larvae captured during samplings were 236 individuals. Larvae were abundant in seagrass beds and coral reefs, making the two habitats suitable for the reserved area. The "no-take zone" area obtained from the analysis protects the biological parameters, less conflict with human activities, and provides minimum cost, which is fulfilled by Scenario 3.

Keywords: Blue swimming crabs; larvae; no-take zone; Spermonde Archipelago

INTRODUCTION

Most of the blue swimming crab (BSC) stocks in Indonesian waters are under fishing pressure (Ernawati *et al*., 2014; Suman *et al*., 2020; Prince *et al*., 2020). Salemo Island in Spermonde Archipelago is one of those locations experiencing high fishing intensities to exploit blue swimming crab (Ihsan *et al*., 2014a; Nurdin *et al*., 2016; Adam *et al*., 2016). Most of the fishing efforts within this area are small scale fishery (SSF) using multiple fishing gears such as gill nets, mini trawls, and traps trawl (Ihsan *et al*., 2014a; Ihsan *et al*., 2014b; Nurdin *et al*., 2015; Nurdin *et al*., 2020). In order to maintain the population and sustainability of the blue swimming crab fishery, a conservation effort need to be attempted by determining a restricted zone.

Benefits of imposing a restricted zone include overcoming the rate of damage and preventing the loss of biodiversity of overexploited populations or habitats (Klein *et al*., 2009; Dahlgren & Tewfik, 2015; Sala & Giakoumi, 2017). The restricted zone proposed within this study is an alternative management to regulate continuous exploitation of the blue swimming crab resource surrounding Salemo Island. The design of the reserve was obtained through Marxan analysis (Metcalfe *et al*., 2015; Esfandeh *et al*., 2015; Levin *et al*., 2015), which is a tool used to design aquatic conservation areas (Anggraeni *et al*., 2017; Firmansyah *et al*., 2018).

According to Robert & Hawkins (2000), mechanisms in improving biomass in a no-take zone can benefit the fishery nearby the zone through: (1) spill over (distribution of young and adult blue swimming crab from the conservation zone to the nearby waters); (2) eggs and planktonic larvae that drift from the zone into its surrounding areas; and (3) prevents overall damage of the population when areas outside the zone are collapsing. Therefore, the determination of the reserved area must address the source of the population (spawning ground and the place where BSCs spend their larval life stages).

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Designing a restricted zone in Salemo Island through the Marxan approach needs scientific information related to female berried crabs (BFC) (Keith & Hutchings, 2012; Nurdin *et al*., 2019; Nurdin *et al*., 2020) and larval abundance (Wibowo *et al*., 2018; Ihsan *et al*., 2019). This research aimed to complete the required data to design the marine reserved in Salemo Island and to identify the zone that will be proposed as a restricted zone.

MATERIAL AND METHODS

Input Files For the Reserved Design

Marxan analysis was employed to determine the extent of a reserved area in Salemo Island. This analysis required two types of data as inputs (input files) regarding the utility of the area surrounding Salemo Island. The first data are data that represent conservation features, while the second data required are those that represent socio-economic features. The conservation feature is defined as the BSC spawning ground i.e. the location with an abundance of berried female crabs (BFC) and; a location with an abundance of larvae. While locations that represent socio-economic features are those where social and economic activities take place.

Of the two types of information required in conservation features, larval abundance data is unavailable prior to this study, while information on BFC was available as a secondary data from Nurdin *et al*. 2019 study. The survey to locate places where BSC larvae were abundant was done within this study. Places where social and economic activities were identified through observations of locals' activities surrounding the Salemo Island.

Upon the identification of places that represent the two features was complete, those locations were assigned as planning units. Subsequently, these planning units were scored to identify the level of importance of each feature.

Scoring Method

Each planning unit was weighted qualitatively ("high" and "low") which reflects the importance of the location ecologically or socio-economically. Those units were also weighted based on the quality of the data. Units with good quality of data available were scored as "high" and conversely, those which only poor data available to support the research were scored as "low". The final score was determined by incorporating the previous two scores. This scoring method were conducted based on the system developed in The Nature of Conservancy workshop (CTC TNC) in 2006 (Darmawan & Darmawan, 2007). This scores refer to the following Table 1.

Table 1. Scoring system for each planning unit

Level of interests	Data quality	Scores
High	High	2
High	Low	1.75
Moderate	High	1.25
Moderate	Low	1
Low	High	0.75
Low	Low	0.25

Source: Darmawan & Darmawan, 2007

Setting Up Protection Scenarios

The next stage in identifying the location for the reserve is to determine the protection scenario. The scenario was selected based on the aim of the reserve. Three aims that are commonly used to identify the reserved area are: (i) to protect places with high diversity; (ii) to protect high productivity areas and; (iii) to protect spawning ground (Kelleher, 1999). The aim of the reserve area developed during this study is to protect the sustainability of the blue swimming crab population. Therefore, the area that will be protected is the spawning ground of the BSC.

To determine the extent of the reserve that must be established to be able to meet the aim. The three levels of target protection (scenarios) were simulated within this study which are areas that will allow 80%, 90% and 95% of protection to the spawning grounds. The total area considered within this study was 147,000 m^2.

Data Collection

Samplings took place on Salemo Island which is located in the inner zone of Spermonde Archipelago (Figure 1). Three stations were established to represent three habitats where BSCs usually spawn. The stations include seagrass beds, coral reefs, and mangroves, with six repetitions done for each habitat. The study covers five months of samplings from March 2015 to July 2015.

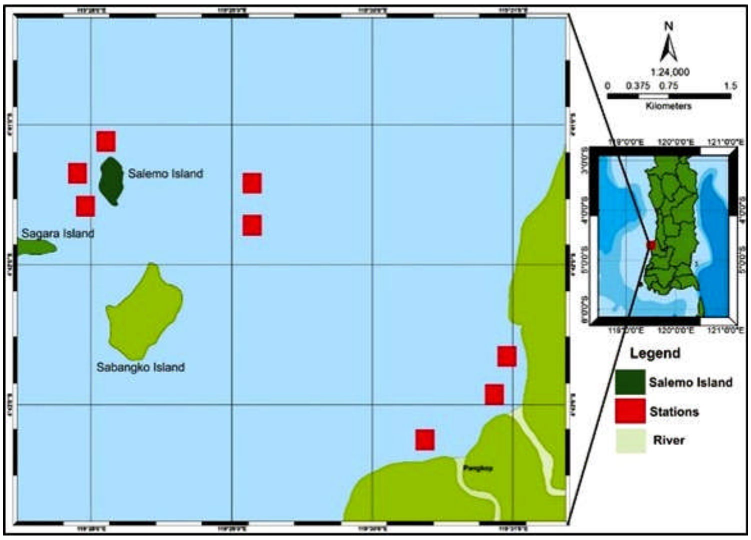

Figure 1. Salemo Island, Spermonde Archipelago.

Larval Abundance

Larvae were collected using a larval net scoop with a mesh size of 56 µm, opening diameter of 70 cm, and net length of 180 cm. The scoops were equipped with a larval chamber where larvae were trapped after being caught. Sampling duration was recorded, and the initial time count was started from the scoop was immersed in the water until the scoop was vertically recovered from underwater. Larvae from the larval chamber were transferred to sample bottles added with 5% formalin. The specimen was stored in a cool box. Samples were transported to *Produktivitas Perairan laboratory of Hasanuddin University* for further analysis.

Larval abundance was calculated based on Yahya & Surahman (2013) as follows:

$$N - \frac{n}{V_{tsr}} \quad \text{...} \quad (1)$$

Where:
N = Larval abundance (ind/m^3)
n = the number of larvae (ind)
Vtsr = volume of filtered water

Volume of filtered water is obtained based on the following formula:

$$V_{tsr} = s \times t \times v \text{..} \quad (2)$$

Where:
s = volume of the scoop (m^3)
t = filtering time (time during immersion underwater)
v = vessel's speed (m/s)

Studentized t-test was employed to compare abundances of the locations (Zar, 2010).

$$t = \frac{\bar{x}_1 - \bar{x}2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad \text{..} \quad (3)$$

where:

$\bar{x}_1$ = the average of abundances from station 1

$\bar{x}_2$ = the average of abundances from station 2

s_1^2 = the variance from sample 1 abundances

s_2^2 = the variance from sample 2 abundances

n_1 = the sample size from location 1

n_2 = the sample size from location 2

Marxan Analysis

Marxan analysis was employed to determine suitable reservation areas to protect the BSC population in Salemo Island. Two features were required in this analysis, i.e. conservation and socio-economic features. Conservation feature consists of berried female crab abundance and larval abundance. The socio-economic feature is constituted by data related to BSC resource exploitation which includes aquaculture locations operating in the area, fishing grounds, and shipping lanes (Table 2). Apart from meeting the aim, the scenario was also developed based on considerations of: (i) high diversity area; (ii) high productivity area and; (iii) spawning area. Beside the above criteria, areas with human activities and resource utilization must also be put into consideration (Supriharyono, 2009).

Table 2. Data sources used in Marxan Analysis

No	Data	Source
1	BFCs abundance	Nurdin *et al.,* 2019
2	Larval density	This study
3	Aquaculture area	Nurdin, 2015
4	Fishing ground	Nurdin, 2015
5	Shipping lane	Nurdin, 2015

Data that have been incorporated into the planning unit will be weighted according to their level of interest quality. The conservation feature with the highest score is considered to achieve the conservation target, and so does the socio-economic feature. There are two parameters in the conservation feature (Table 3 and Figure 2) and three parameters in the socio-economic feature (Table 3 and Figure 3). These features were given scores ranging from 1 to 2.

Tabel 3. Conservation and social-economic feature

No	Feature	Parameters	Scores
1	Conservation	Female berried abundance	2
		Larvae abundance	2
2	Socio-economic	Shipping lane	1
		Seaweed aquaculture	2
		Fishing ground	2

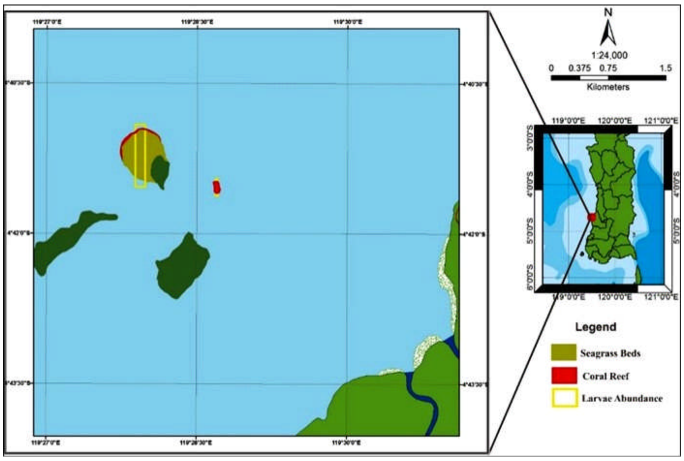

Figure 2. Conservation feature.

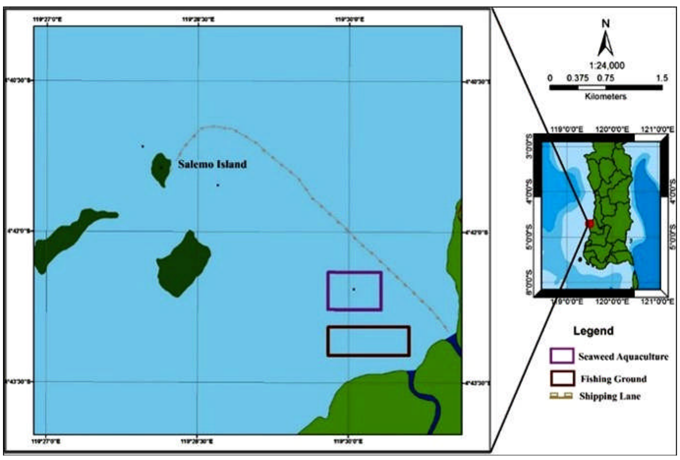

Figure 3. Socio-economic feature.

The scale of conservation targets depends on the scale of area that will be converted into a take zone. The spawning ground is usually marked by the high abundance of BFC and high density of the larvae. Therefore, the two locations are considered as the spawning grounds for the BSCs.

RESULT AND DISCUSSION

Results

Larval Abundance

The data on the abundance of the larvae shows an increasing trend towards July (Figure 4). The lowest number of catches occurred in March while the highest occurred in July when the larvae density reached 49 individuals/m^3 in seagrass beds. In March and April, larvae were more abundant in coral reef ecosystems, while during the rest of the sampling period (May-July), the larvae caught in seagrass beds are more numerous compared to those in the coral habitat. However, the student t-test result (at a 95% level of significance) does not confirm the significant differences of larval abundance between the two types of habitat. During five months sampling period, no larval specimens were found in mangrove ecosystems.

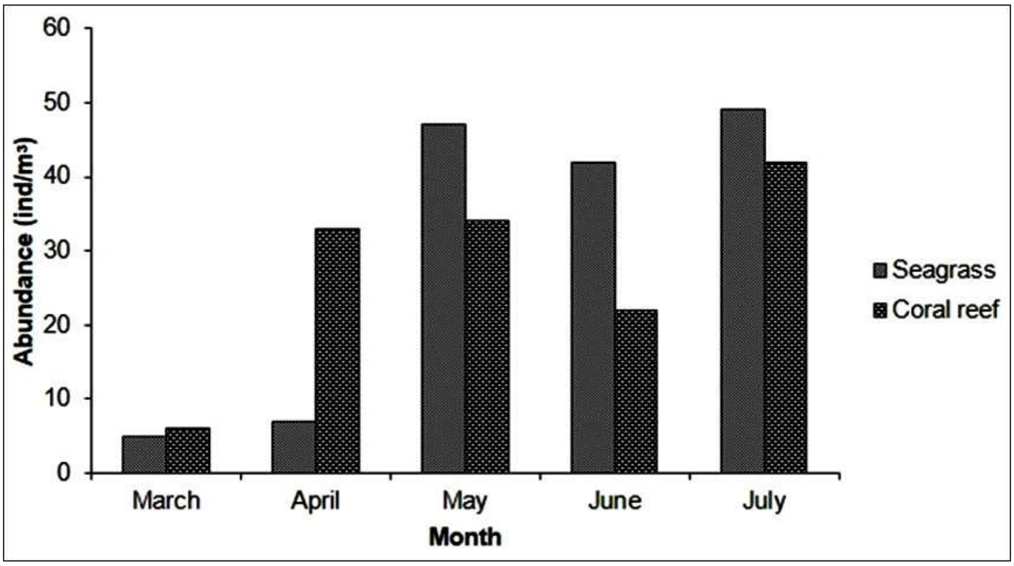

Figure 4. The abundance of blue swimming crab larvae on monthly basis.

The number of Planning Unit

From surveys that were conducted during the research, areas with high density of larvae were identified to cover 11,000 m^2, and areas with high abundance of BFC covered 5,700 m^2. Those locations were assigned as planning units. These two types of areas was considered as the 100% of coverage for the reserve. The complete description of the 100% coverage can be seen in Table 4 below:

Observations that were made to the social and economic activities of local people nearby the Salemo Island were able to identify three important locations which consist of a shipping lane, seaweed cultivation, and fishing ground. These locations are described in Figure 5.

Table 4. Survey results that covers locations under conservation features

Feature	Parameters	Area (m^2)	Number of Planning Unit
Conservation	BFC abundance	5,700	11
	Larval abundance	11,000	8
	Total	16,700	

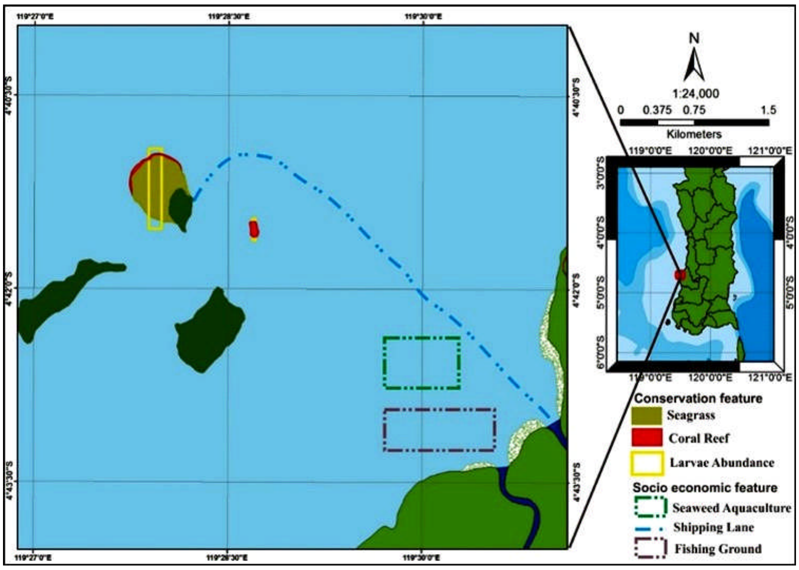

Figure 5. Conservation and socio-economic feature.

Targeted Planning Units and Their Scores

As the target of the "no-take zone" was expected to meet 80-95% of the conservation features, three scenario (level of protections) which then was adjusted to the target percentage. These scenarios and their conversion to the percentage are described in Table 5.

Table 5. Final weight and targetted planning units for the reserved area

Scenario (level of protection)	Parameters	Score	Target (%)	Targetted Planning Unit
95%	Larval abundance	2	95	10.45
	Berried female abundance	2	95	7.6
90%	Larval abundance	2	90	9.9
	Berried female abundance	2	90	7.2
80%	Larval abundance	2	80	8.8
	Berried female abundance	2	80	6.4

*Within this analysis, socio-economic features were not targeted for the reserved zone because the locations are being used for human activities. Including those locations in the reserved is usually resisted by users. Therefore, those locations were excluded from the targeted area that will be included in the reserved.

Reserve Design

Based on data analysis results from 95% of protection from Marxan (Figure 6), it is seen that the recommendation for the reservation area (no-take zone) is 15,000 m^2 whilst in scenario 2 (Figure 7) the recommendation area is centered on the west part of Salemo Island with total extant 5,000 m^2. In scenario 3 (Figure 8), the recommended area is located on the west and east parts of the island extending 11,000 m^2. The red gridded area show recommended locations for the no-take zone because its frequency being selected is the highest among any other planning unit.

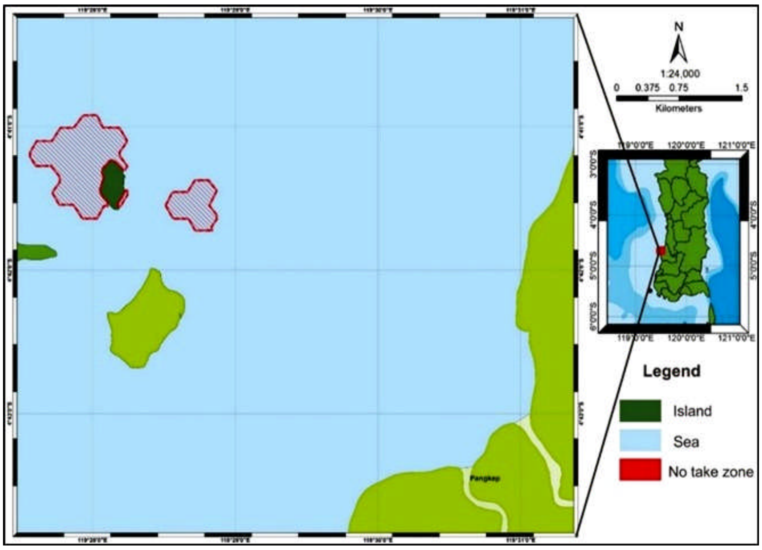

Figure 6. Blue swimming crab no-take zone (Scenario 1).

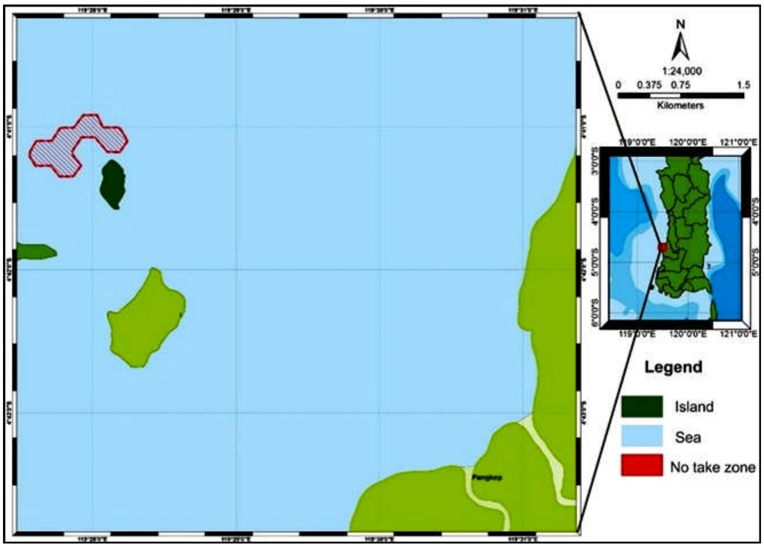

Figure 7. Blue swimming crab no-take zone (Scenario 2).

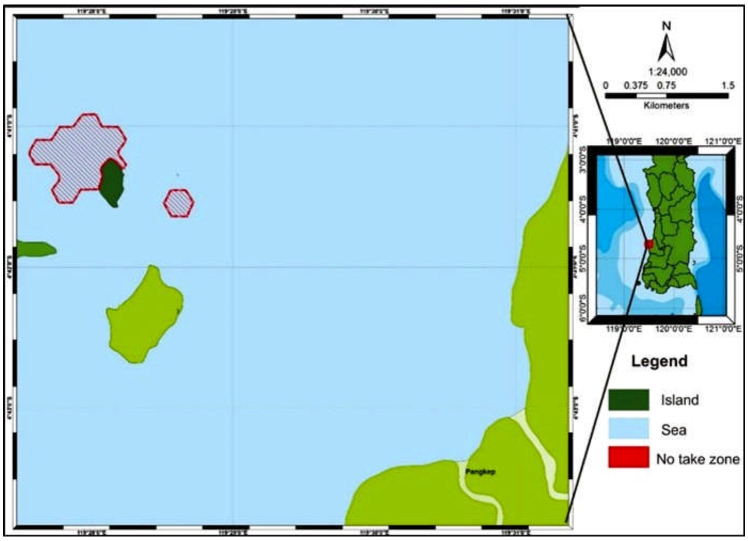

Figure 8. Blue swimming crab no-take zone (Scenario 3).

The results of the three scenarios provided different designs for the no-take zone and each design has different characteristics. Therefore, the determination of the reservation area must be adjusted with the aim and accepted target (Table 5).

Discussion

Larvae have critical roles in BSCs sustainability because it holds the key in increasing recruitment and stock (Kunsook *et al*., 2014; Zairion *et al*., 2014; Kembaren & Surahman, 2018). Information on larvae location is important in determining nursery and spawning ground (Amri *et al*., 2015; Wagiyo *et al*., 2019). Tantichaiwanit *et al*., (2010) reported that the highest abundance of brachyurans (including blue swimming crab larvae) occurs in seagrass beds because those areas are shelters to brachyuran larvae. Their larvae do not live in mangrove ecosystems or estuaries as they are catadromous animals (Sahoo *et al*., 2011) where spawning and adult phases take place in the sea (Andrade *et al*., 2014).

The above findings were consistent with the finding of this study where larvae are abundant in coral reefs and seagrass beds. The two habitats can be considered as the source of the population because the two places also host the berried female crabs during the spawning season (Nurdin *et al*., 2019). Therefore, the best candidates to propose as a reserve is an area that covers the two habitats (coral reefs and seagrasses) where BFCs and larvae were found to be abundant i.e., Scenario 1 (Figure 6) and Scenario 3 (Figure 8). On the other hand, the area that is shown in Figure 7 (Scenario 2) can only protect coral reefs in the northwest of the island and the seagrass beds partially while it neglects the coral reefs in the southeast of the island. Therefore, scenario 2 can be omitted from the candidate location.

The “no-take zone” area development needs to be in line with the interests of stakeholders for best management practices (Bennett & Dearden, 2014; Halik *et al*., 2018). The larger the zone, the more blue swimming crab population can be protected (Vandeperre *et al*., 2011). In fact, a reserved area can create conflict due to the utilization of the area for human activities, which bear the cost if it is imposed. The larger the conflicted area, the higher the cost of a reserve (Mangi & Austen, 2008). A Larger reserve also required larger costs for monitoring to ensure its efficacy and compliance.

Results from this study show that the two locations proposed as reservation areas are not conflicted with areas under human utilization. However, the area proposed in Figure 6 (Scenario 1) also covers places where both berried female crabs and larvae were not found (at the southeast of the island) which is unnecessary to be included in the design. Including the unproductive areas will increase costs, but minimum yields can be derived from these places. Therefore, from the above discussion, the suitable design to propose as a reserved area is those included in Figure 8 (Scenario 3.) because it equally supports the spawning ground as Scenario 1, but imposes a lesser cost. The size of the reserved area for the BSC in this study is very small due to the limited coverage of Salemo Island. The island is surrounded by other islands which have similar characteristics to the Salemo in Spermonde Archipelago. Therefore, studying the sole island to create a marine protected area may be unsatisfactory to protect the larger populations of BSC. Ideally, to sustain as many as possible BSC populations, networks and connectivity among habitats need to be established through larval dispersal study, by including other islands and larger areas within the research.

CONCLUSION

BSC larvae are abundant in seagrass and coral reef ecosystems. The two habitats can be considered as the spawning ground of the blue swimming crabs in Salemo Island and its surroundings. The no-take zone area recommended in this study comes from Scenario 3 where it can protect the BFCs and larvae of blue swimming crabs at a lesser cost.

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