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Fisheries Management of Blue Swimming Crab (*Portunus pelagicus*) based on Zoning Area in Pangkep Waters, South Sulawesi, Indonesia

Ihsan¹, Kasmawati¹, Ernaningsih¹, Asbar² and Asmidar²

¹Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Science, Muslim University of Indonesia, Makassar, Indonesia

²Department of Marine Science, Faculty of Fisheries and Marine Science, Muslim University of Indonesia, Makassar, Indonesia

Email: ihsan.ihsan@umi.ac.id

Abstract. Blue swimming crab *Portunus pelagicus* is one capture fisheries commodity which offers promising prospects in Pangkep Regency, South Sulawesi, Indonesia. This study aimed to determine the fishery management of blue swimming crab based on spatial zoning areas. The research was conducted between April- November 2016 and May-November 2017 in the coastal waters of Pangkep Regency. Primary and secondary data were collected and analysed for water suitability and zonation using mapping and geographic information system analysis (GIS). The water quality parameters were: dissolved oxygen (1.5-11.0 mg/L), temperature (31-37 °C), salinity (9.0-31.0 ppt) and pH (6-8). The fishery management of blue swimming crab was classified into two integrated zoning area types: conservation zone (56,855 Ha) and commercial blue swimming crab fishery zone (36,153 Ha). However, the conservation zones are opened to the commercial fishery at certain times outside the critical periods for blue swimming crab reproduction. These critical periods are the zoea, megalopa and juvenile crab phases which occur from May to October, with an annual spawning peak in August. Fishing is not allowed in the conservation zone during the critical periods in order to accommodate sustainable exploitation. The findings were based on data analysis of water quality suitability, existing environmental conditions, fishing grounds, and the life cycle of blue swimming crab, overlaid on the 2013 zoning plan for the coastal area and small Islands in Pangkep Regency.

1. Introduction

Portunus pelagicus or blue swimming crab is a species of decapod crustacean which is commonly found in shallow, coastal and estuarine tropical waters throughout the Indo-West Pacific [1]. In particular, this species is also widespread around Sulawesi in central Indonesia [2]. However, the species is not evenly distributed throughout these waters due to spatial and temporal variations in environmental conditions. During the spawning period, blue swimming crab are mainly found offshore; while during the growing period, feeding, nurturing, sheltering grounds are mostly located in coastal ecosystems. In general, the blue swimming crab life cycle consists of zoea, megalopa, juvenile and adult phases, most of which occur in coastal waters. The zoea, megalopa and juvenile stages are often referred to as critical periods or stages during which the crabs are susceptible to predation and environmental change [3]. These factors contribute to the high natural mortality during these stages of the crab life-cycle.



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Blue swimming crab is an economically important commodity in the fisheries sector, supporting the livelihoods of many local fishermen, especially in Pangkep Regency. This species has tasty flesh with a high protein content making it a sought-after fisheries commodity. Local market price for blue swimming crab ranges from IDR.40,000 to IDR.50,000 [4]. The demand comes not only from the local market but also the International market, including the industrial seafood sector. Consequently, many local fishers have been tempted to start catching crabs rather than finfish.

The expansion of unregulated exploitation has increase pressure on blue swimming crab populations, resulting in declining abundance in the wild. Commonly used fishing gear includes gill-nets and traps [5]. Furthermore, the blue swimming crab fisheries have been operating without considering the critical periods of the crab life-cycle. Moreover, several other activities in Pangkep waters can cause mass mortality of zoea, megalopa and juvenile crabs. For instances, the “sero net” which is used as a fish trap, however, the crabs are often trapped in this passive fishing gear and are preyed on by seabirds. Juvenile crabs also are caught in lift nets and harvested with seaweed. In order address these issues, appropriate fisheries management approaches are required.

Zonation based crab fisheries management is one potentially effective management tool which could be applied to promote the recovery of depleted wild crab populations, especially through protection for the zoea, megalopa, and juvenile stages which are most critical times for the crab to be protected. This could be done by creating a temporary buffer zone for crab protection from fishing activities in Pangkep Regency. The closure of the zoned area would remain in effect until the crabs reached a commercial size. Therefore, the aim of this study was to investigate blue swimming crab fisheries management based on zonation in Pangkep waters.

2. Materials and Methods

2.1. Study Area

This study was conducted in the coastal areas of Pangkep Regency (Figure 1). The research took place during April-December 2016 and April -December 2017

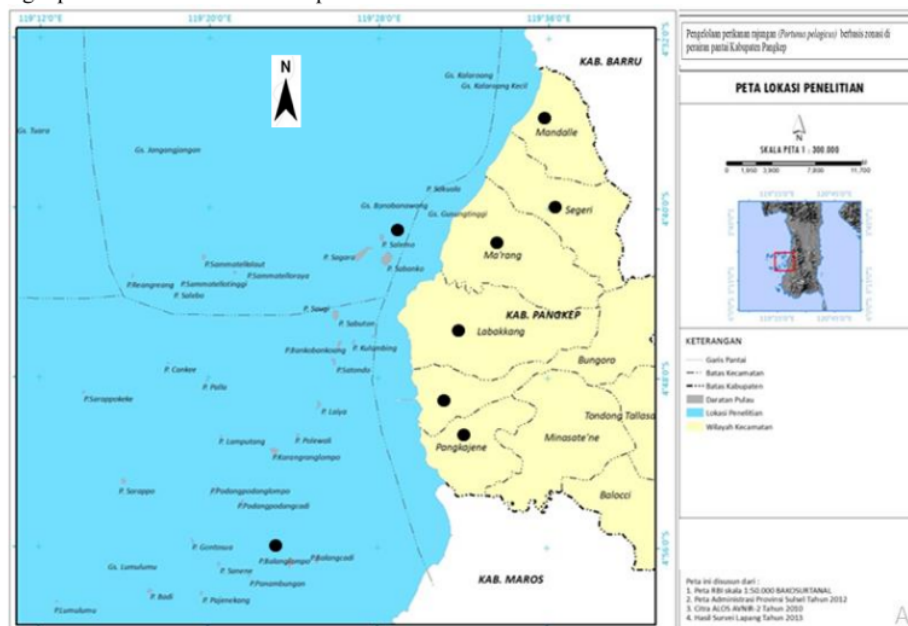


Figure 1. Blue swimming crab sampling sites in Pangkep, South Sulawesi, Indonesia

2.2. Sampling procedures

Primary data were collected on the distribution of zoea, megalopa, juvenile and adult crabs. Zoea and megalopa crab sampling followed Fachrul [6]. A plankton net (0.45 m diameter, 2.10 m of length and mesh size of 0.50 mm) was used for juvenile crab sampling (Figure 2). The sampling method was intended to determine the horizontal distribution of zoea and megalopa. The plankton net was lowered in a certain sampling spot and towed behind a boat to the next sampling spot. A total of 40 sampling spots were used. The amount of filtered water was obtained by multiplying the distance between the start and end points with the diameter of the plankton net. Sampling locations were recorded using a GPS (global positioning system) unit. Water temperature (thermometer), salinity (salinometer), dissolved oxygen (DO meter), and pH (pH meter) were recorded. Adult crabs were sampled using a boat and fishing gear (crab gillnet and traps called 'bubu'). Sample bottles and a cold box were also used for collecting and preserving samples to be analysed in the laboratory.

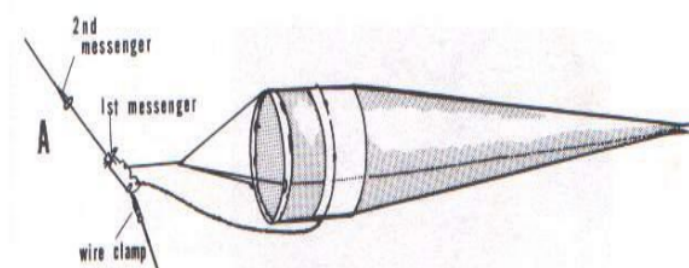


Figure 2. Plankton net used for crab sampling

Primary data on crab production were collected from local fishers using a questionnaire. The variables recorded included the number of fishing trips and the fishing gear used. In addition, secondary data were obtained from other related institutions, universities and local government of Pangkep Regency. In particular, data and information related to the 2013 zoning plan for the coastal area and small islands of Pangkep Regency. Visual records were made using a digital camera.

2.3. Data analysis

The zoea and megalopa crab samples were analysed at the water quality laboratory of the Pangkep Agricultural State Polytechnic. For qualitative and quantitative analysis, various formulae were used. Data on temperature, salinity, oxygen, and pH were tabulated and analysed descriptively. Various types of analysis consisted of laboratory analysis, qualitative and quantitative analysis.

A geographic information system (GIS) was used for the spatial zonation analysis using the ArcView platform, in order to determine the spatial distribution of the life cycle phases of blue swimming crabs in Pangkep waters. This analysis involved several steps, including radiometric corrections, geometric corrections, image sharpening, and image classification. Matrix and conformity criteria were provided for the crab life cycle management suitability analysis, according to Ihsan [7]. Details of the suitability analysis are shown in Table 1.

Table 1. Criteria for determining the suitability of an area

No	Class Interval	Categories
1	$X_0 (= \text{min value}) - X_1 (= X_0 + C_i)$	unsuitable (N)
2	$X_1 - X_2 (= X_1 + C_i)$	acceptable (S2)
3	$X_2 - X_3 (= \text{max value})$	suitable (S1)

Note: X_0 : lower limit of assessment scale; X_1 : limit between unsuitable and acceptable class
 X_2 : limit between acceptable and suitable class; X_3 : upper limit of assessment scale

An approach based on water quality suitability was applied for the zoea, megalopa, juvenile and adult crabs. The suitability matrices for this analysis are presented in Table 2 to Table 5. The criteria for the determination of area suitability are shown in Table 6.

Table 2. Suitability matrix for blue swimming crab zoea

Parameters	Suitable category				Unsuitable category		
	Weight	Description of suitable parameters	Score	Total score	Description of unsuitable parameters	Score	Total score
Temperature	0.40	27°C - 33°C	2	0.80	<27°C or >33°C	1	0.40
Salinity	0.30	30- 35 ‰	2	0.60	<30 or 35 ‰ >	1	0.30
Dissolved oxygen	0.20	3,52ppm - 6 ppm	2	0.40	<3,52 ppm or >6 ppm	1	0.20
pH	0.10	7,0- 8,5	2	0.20	<7,0 or >8,0	1	0.10
	1.00	Total maximum score		2.00	Total minimum score		1.00

Table 3. Suitability matrix for blue swimming crab megalopa

Parameters	Suitable category				Unsuitable category		
	Weigh	Description of suitable parameters	score	Total score	Description of unsuitable parameters	score	Total score
Temperature	0.40	28°C - 34°C	2	0.80	<28°C or >34°C	1	0.40
Salinity	0.30	28-34 ‰	2	0.60	< 28 or 34‰ >	1	0.30
Dissolved oxygen	0.20	4-6 ppm	2	0.40	< 4 ppm or >6 ppm	1	0.20
pH	0.10	7,0-8,0	2	0.20	<7,0 or >8,0	1	0.10
	1.00	Total maximum score		2.00	Total minimum score		1.00

Table 4. Suitability matrix for blue swimming crab juveniles

Parameters	Suitable category				Unsuitable category		
	Weigh	Description of suitable parameters	score	Total score	Description of unsuitable parameters	score	Total score
Temperature	0.40	28°C-30,5°C	2	0.80	<28°C or >30,5°C	1	0.40
Salinity	0.30	26-27 ‰	2	0.60	< 26 ‰ or 27 ‰ >	1	0.30
Dissolved oxygen	0.20	4-6 ppm	2	0.40	< 4 ppm or > 6 ppm	1	0.20
pH	0.10	7,0-8,0	2	0.20	<7,0 or >8,0	1	0.10
	1.00	Total maximum score		2.00	Total minimum score		1.00

Table 5. Suitability matrix for adult blue swimming crabs

Parameters	Suitable category				Unsuitable category		
	Weigh	Description of suitable parameters	score	Total score	Description of unsuitable parameters	score	Total score
Temperature	0.40	28°C - 31 ⁰ C	2	0.80	<28°C or >31°C	1	0.40
Salinity	0.30	31‰ -36 ‰	2	0.60	< 31‰ or 36 ‰ >	1	0.30
Dissolved oxygen	0.20	4-6 ppm	2	0.40	< 4 ppm or >6 ppm	1	0.20
pH	0.10	6,78 - 8,0	2	0.20	<6,78 or >8,0	1	0.10
	1.00	Total maximum score		2.00	Total minimum score		1.00

Table 6. Determination of area suitability category

Interval class	Category
1.00 – 1.33	not suitable (N)
1.34 – 1.67	fairly suitable (S2)
1.68 – 2.00	suitable (S1)

3. Results and discussion

3.1. Water quality parameters.

The survival of planktonic blue swimming crab larvae is largely determined by water quality due to the high susceptibility of these larvae to water quality changes⁸. The ranges of the water quality parameters recorded across all observation stations are provided in Table 7.

Table 7. Water quality measurements taken during the study period

Water quality parameters	Results
Dissolved oxygen	1.5 – 11.0 mg/L
Temperature	31.0 – 37.0 °C
Salinity	9 – 31.6 ‰
pH	6 – 8

Dissolved oxygen measurements obtained from several stations throughout the coastal waters of Pangkep were relatively low (1.5 to 4.5 mg/l). Further offshore, higher dissolved oxygen levels were recorded (4.6-7.5 mg/L and 7.6- 11.0 mg/L). The dissolved oxygen measurements across all stations ranged from 3.5 ppm to 10.7 ppm, within the range suitable for the growth and early life development of crabs: zoea, 3.52 ppm - 6 ppm; megalopa, 4 ppm- 6 ppm; and juvenile, 4 ppm-6 ppm [9,10].

Water temperatures measured during this study were relatively high, ranging from 31 °C to 37.0 °C. These temperatures are suitable for crab zoea and megalopa stadia. Optimal temperatures reported for various life stages include 30°C for zoea, 27 °C to 32 °C for megalopa and 28°C and 30.50°C for crablets [10,11]. Male blue swimming crabs have been reported as being more active than female crabs at a temperature of 30°C [12]. However, the temperature of crabs in their natural habitat generally ranges from 25 °C to 32 °C [10]. Furthermore, brood-stock rearing, egg hatching and larviculture should be carried out at a temperature range of 28-31 °C. In fact, the blue swimming crab is widely distributed across the tropical and the subtropical regions of the world, which indicates that this crab is a eurythermal organism with a broad temperature tolerance [13].

Salinity measured during the study period ranged from 7 ppt to 35.0 ppt. This is within the reported tolerance for this species of 11 to 53 ppt [14]. Although crabs can survive at salinities below 11 ppt, such low salinity levels may hamper growth, especially in early stages, as well as organ development [15]. In addition, mortality tends to be higher at salinities ≤ 15 ppt and > 45 ppt. This is consonant with the fact that many blue swimming crabs are found in riverine waters during the dry season. However, the crabs leave the river in the rainy season. Some local fishermen often capture blue swimming crabs laying eggs in the river.

The pH values measured ranged from 6 to 8. A pH of 6.78 can still be tolerated by crabs [9], although the optimum pH range for crab growth is reported as 7.5-8.5 [10] and the recommended pH for larval rearing is 8-8.5 at 100 ind/L density [11]. Furthermore, the optimum pH for the early crab life stages have been reported as: zoea, 7.0-8.5; megalopa, 7.0-8.0; and juvenile, 7.0-8.0 [16,17].

3.2. Distribution of the crab life cycle

According to water quality data (temperature, salinity, dissolved oxygen and pH) of distributed zoea formed two different conformity classes, which were 'suitable' (200.465 ha) and "unsuitable" (2.401 ha). The respective areas are given in Table 8.

Table 8. Zone coordinates for the zoea distribution

Type	coordinates		Compliance Criteria
	X	Y	
Zoea	119°32' 9.404" E	4°39' 33.337" S	unsuitable
	119°29' 48.618" E	4°50' 38.105" S	unsuitable
	119°22' 32.988" E	4°44' 28.495" S	suitable

For megalopa stadia, there were also 2 classes; "suitable" (176.869 ha) and "unsuitable" area (25.997 ha). The respective areas are given in Table 9.

Table 9. Zone coordinates for the megalopa distribution

Type	coordinates		Compliance Criteria
	X	Y	
Megalopa	119°30' 29.970" E	4°35' 45.975" S	unsuitable
	119°32' 56.870" E	4°37' 29.961" S	unsuitable
	119°30' 40.231" E	4°40' 52.010" S	unsuitable
	119°29' 40.503" E	4°48' 46.660" S	unsuitable
	119°29' 50.906" E	4°49' 15.547" S	unsuitable
	119°28' 37.778" E	4°47' 38.017" S	unsuitable
	119°27' 59.897" E	4°57' 39.438" S	unsuitable
	119°28' 58.622" E	4°51' 15.148" S	unsuitable
	119°20' 59.341" E	4°44' 51.989" S	suitable
	119°34' 40.962" E	4°35' 25.983" S	suitable
	119°32' 8.097" E	4°34' 49.986" S	suitable
	119°31' 22.580" E	4°38' 4.327" S	suitable
	119°29' 15.622" E	4°48' 9.779" S	suitable
	119°30' 14.293" E	4°52' 51.141" S	suitable

According to water quality data (temperature, salinity, dissolved oxygen and pH), the distribution of juvenile crabs formed two different conformity classes, which were 'suitable' area (193.724 ha) and "unsuitable" area (91.430 ha). These areas are defined in Table 10.

Table 10. Zone coordinates for the juvenile crab distribution

Type	coordinates		Compliance Criteria
	X	Y	
Juvenile crab	119°33' 21.084" E	4°37' 17.923" S	unsuitable
	119°32' 6.149" E	4°39' 21.744" S	unsuitable
	119°30' 52.781" E	4°41' 37.941" S	unsuitable
	119°29' 51.164" E	4°41' 53.228" S	unsuitable
	119°28' 7.117" E	4°47' 20.650" S	unsuitable
	119°28' 39.313" E	4°48' 24.007" S	unsuitable
	119°29' 40.707" E	4°48' 33.252" S	unsuitable
	119°28' 28.941" E	4°57' 31.581" S	unsuitable
	119°28' 58.484" E	4°51' 52.555" S	unsuitable
	119°25' 59.498" E	4°45' 15.815" S	suitable

The results above showed that the suitable areas for zoea, megalopa and young crabs were still more extensive than the unsuitable areas. This indicates that the growth and development of zoea, megalopa and young crabs can be supported by good water quality. The water quality data (temperature, salinity, dissolved oxygen, and pH) suitable for adult crabs, and the coordinate points of the fishing ground of crabs in the coastal and island waters indicate a suitable location extent of 89.131 ha (Table 9). Data for "unsuitable location" for adult crabs (4.577,6 ha) is also shown in Table 11.

Table 11. Zone coordinates for the adult crab distribution

Type	Coordinates		Compliance Criteria
	X	Y	
Adult crab	119°33' 21.132" E	4°37' 37.458" S	unsuitable
	119°30' 40.064" E	4°41' 53.544" S	unsuitable
	119°29' 37.686" E	4°48' 39.476" S	unsuitable
	119°29' 52.760" E	4°49' 18.161" S	unsuitable
	119°29' 1.044" E	4°57' 36.279" S	unsuitable
	119°21' 42.936" E	4°45' 51.030" S	suitable

3.3. Fisheries management based zoning

Zoning is a form of engineering which utilise the space through the determination of functional boundaries. This is in accordance with the potential resources and carrying capacity and ecological processes that take place as a unity in the coastal ecosystem. While the zone is a space used for mutually agreed between various stakeholders and has been established legal status [18].

Data on local crab production, collected from fishermen for a year in subdistrict in Pangkajene such as Bungoro, Liukang Tupabbiring and North Liukang Tupabbiring, Labakkang, Ma'rang, Segeri, Tanjung Butung Labbakang, were about 231.540 kg/year with an average of 19.295 kg/month. The fisheries management for fishing crab based on zoning has been regulated in which zoea, megalopa and juvenile crabs are protected in the conservation zone. The utilization zones for crabs are also provided (Table 12). In order to prevent conflicts of interest, the zoning was overlaid the zoning plan map for coastal areas and small islands of Pangkep Regency.

Table 12. Zones in the management of shrimp-based crab-based fisheries in Pangkep District

Zones	Area coverage (Ha)
Port	1.084
Sailing route	11.069
Aquaculture	809
Residency	225
Migrated species route	35
Natural disaster area	1,92
Reserve forest	143
Coastal and small islands conservation	867
Boundaries	188
Tourism	339
Aquatic conservation	24.352
General fishing	70.735
Utilization/fishing ground for crab	36.153
Protective zone/conservation zone	56.855

The conservation zone for crab coverage area was 56,855 ha and the utilization zone was 36,153 Ha. The critical period of crab occurred from May to October in Pangkep regency waters [7]. The spawning peak was on August each year. A temporary closure for six months per year is required. This is important to accommodate protection for the crab during its critical period. Zoning map for fishing crabs management can be seen below:

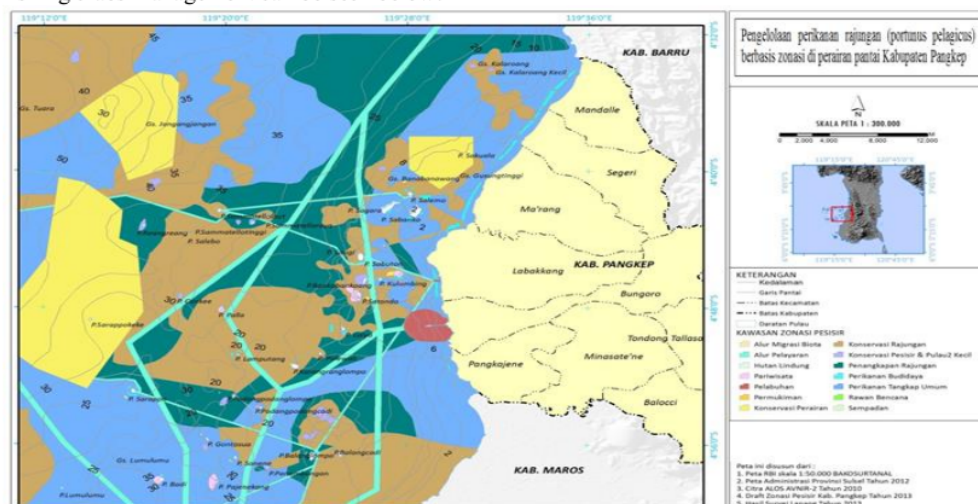


Figure 3. Fisheries management for crabs based on a spatial zoning approach in coastal and marine areas of Pangkep Regency (black: blue swimming crab fishing zone; brown: blue swimming crab conservation zone; yellow: marine conservation zone; blue: general fishing zone)

The implementation of fisheries management for crabs based on zoning may have weaknesses. Moreover, there is a change in the distribution of crabs at zoea and megalopa stages. Lastly, this plan requires support from many stakeholders to work effectively and efficiently.

4. Conclusions

The management of the aquaculture for blue swimming crab was divided into two different classes which suitable and unsuitable. However, a coordinate location for suitability area for life cycle of swimming crab was in the similar coordinates. The suitable area was larger than unsuitable areas.

The distribution of crab life cycle based on zoea and megalopa sampling were in low, medium and high density category. The average number of young crab daily caught ranged from 107 to 208 crabs/fishermen and adult crabs 231,540 kg/per month. Two different buffer zones; conservation zone (56,855.53 Ha) and utilization zone (36,153.65 Ha) were applied for sustainable of blue swimming crab.

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