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Stock Status and Fisheries Exploitation of Blue Swimming Crab *Portunus pelagicus* (Linnaeus 1758) in Lasongko Bay, Central Buton, Indonesia

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Abstract

Research on the stock status and exploitation of the blue swimming crab *Portunus pelagicu*s (Linnaeus 1758) in Lasongko Bay was conducted from April 2013 to March 2014. Blue swimming crabs were sampled monthly using gillnets and traps. Data on the number of fishermen and crab fishing gear were obtained via census and from secondary data and were analysed descriptively for every sampling period. Total catches of crabs were analysed using one-way ANOVA and *t*-test at p= 0.05. The status of crab stock was analysed using a Beverton–Holt model. The results showed that the number of fishing gear increased rapidly from 2006 to 2014, but was not proportional to the increases in crab catches, while the number of fishermen declined. The number of fishing gear and catch in 2006 and 2014 were 2,670 and 15,355 units and 44,194.56 kg and 66,926.6 kg, respectively. Daily crab catch were significantly different between the months. Crab stocks have been overfished and are currently considered critical, and thus the implementation of effective management is necessary.

Introduction

The blue swimming crab *Portunus pelagicus* (Linnaeus 1758) is an economically valuable fishery commodity and is the main export of Indonesian fisheries. The volume and value of blue swimming crab and mangrove crab exports from Indonesia in 2011 were 156,993 tonnes valued at US$ 208,424 million (Ministry of Marine Affairs and Fishery 2012).The catching of crab has intensifies with the increase in demand, however, there is no effective management and may have a negative impact on the sustainability of the crab fishery.

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For the proper management of the crab fishery information is required for the stock status, including the exploitation rates, growth and mortality parameters (Sugilar et al. 2012). Some earlier studies have reported that at the current rate of exploitation, crab stocks in general have been overfished, although this varies among geographic locations such as the Persian Gulf (Kamrani et al. 2010), Oman (Mehanna et al. 2013), Iran (Safaie et al. 2013), India (Dineshbabu et al. 2008 and Sukumaran 1995), Pakistan (Afzaal et al. 2016), Thailand (Sawusdeeet al. 2009 and Kunsook et al. 2014) and Indonesia (Muhsoni and Abida 2009; Kembaren et al. 2012; Ernawati 2013; Hamid and Wardiatno 2015). Before 2010, research in the reproductive biology, population dynamic parameters, and exploitation rates of crabs in Indonesia was rare (Kembaren et al. 2012), even though such information provides the basis for determining stock management strategies for crabs. Several studies of the reproductive biology of crabs in Indonesian waters have been conducted (Kembaren et al. 2012; Sunarto 2012; Ernawati 2013; Ihsan et al. 2014; Zairon et al. 2014a,b; Zairon et al. 2015a,b; Hamid et al. 2015; Hamid et al. 2016a,b).

In addition, some crab exploitation rates and population dynamic parameters have been recently studied by Muhsoni and Abida (2009), Kembaren et al. (2012), Sunarto (2012), Ernawati (2013), Ihsan et al. (2014), and Hamid and Wardiatno (2015). The results of these studies have shown that the population dynamic parameters (such as growth parameters, recruitment, and mortality) and exploitation rates of crabs varied among locations. Studies of crab population dynamics and exploitation rates are generally conducted in open coastal waters, but rarely studied in semi-enclosed bay stocks.

Lasongko Bay is a semi-closed water body with an area of about 33.6 km^2. Crab fishery has been active in these waters since the 1970s, but initially, the intensity remained low (Hamid 2011). Since the early 2000s, the demand for crabs in Lasongko Bay has increased due to the lucrative crab meat processing export business from the area. This has intensified crab catch in the bay area, which is generally shallow and covered by seagrass. The stock status and exploitation rate of crabs in Lasongko Bay have previously remained uncertain, and this lack of information has been a barrier to the provision of rational management efforts for crabs in these waters. This study was aimed to determine the stock status and exploitation rates of the crab fishery as a basis for devising crab management efforts for Lasongko Bay. The findings might be helpful for better and more sustainable management of the blue swimming crab in Indonesian waters.

Materials and Methods

This study was conducted from April 2013 to March 2014 in Lasongko Bay. The bay is located between latitudes of 05^{o}15'S and 05^{o}27'S and longitudes of 122^{o}27'E and 122^{o}33'E (Fig. 1). Crab sampling was conducted monthly using bottom gillnets with mesh sizes of 3.81, 6.35, and 8.89 cm. The three mesh sizes were assembled in a series of single-unit crab gillnet with a height of about 75 cm. The numbers and sexes of blue swimming crabs caught during each sampling were recorded, along with their weights (g) and carapace widths (mm).

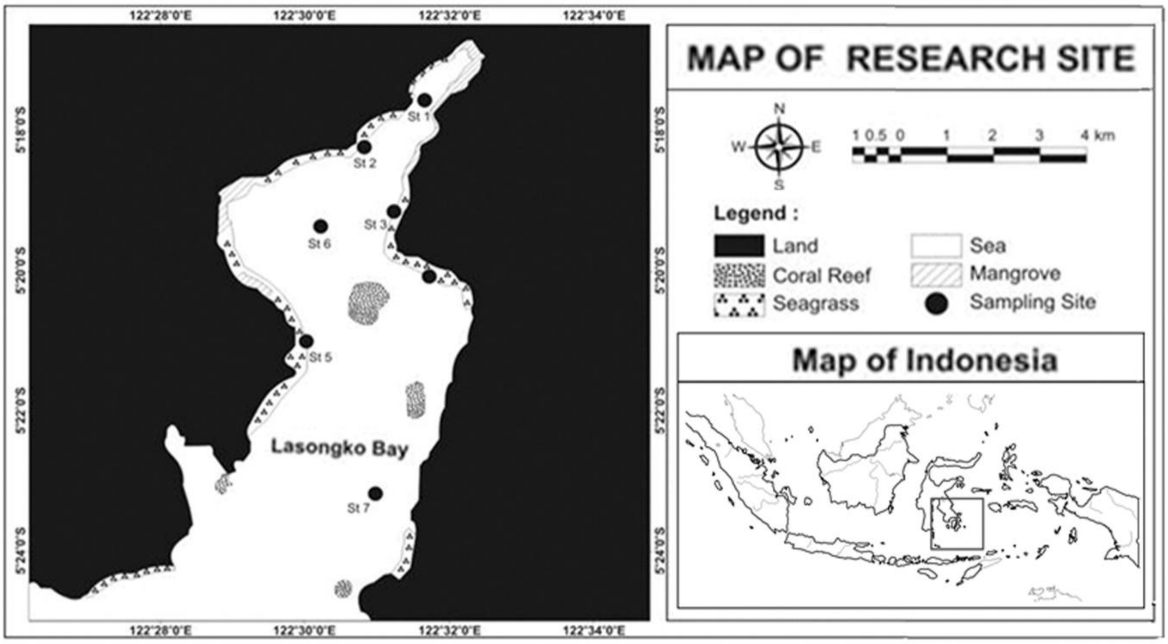

Fig.1. Map showing the location of the study site in Lasongko Bay-Central Buton, Southeast Sulawesi, Indonesia. Black dots indicate sampling sites (adapted from Hamid et al. 2016a).

Data on fishermen and their fishing gear were obtained via the censuses of 11 crab fishing villages and 3 crabmeat processors in the area. In addition, comparative data were also sourced from previous crab research in Lasongko Bay, *i.e*. Hamid et al. (2006) and Hamid (2011). Data on fishermen, fishing gear, and crab catches for each sampling were analysed descriptively. Data on total daily and monthly crab catches were analysed using one-way analysis of variance (ANOVA) with Tukey's *post hoc* testing, and seasonal catches were analysed with *t*-tests (Steel and Torrie 1992) at p= 0.05.

The male and female carapace width data were pooled to determine crab population and stock parameters. The carapace width data were used to determine length frequency distributions in10-mm width classes. The growth parameters for crab carapace width were estimated using the von Bertallanffy growth equation, $L_t = L_\infty (1 - e^{-k(t-t_o)})$ (Sparre and Venema 1998), and total mortality (Z) was based on data curve catches for converted length (Pauly 1984; Sparre and Venema 1998); both were calculated using FISAT II (Gayanilo et al. 2005). The theoretical size at age 0 (t_0) was determined with the equation, $Log_{10}(-t_0)=-0.3922-0.2752\ Log_{10}L_\infty-1.038\ log_{10}K$ (Pauly 1984). Natural mortality (M) of crabs were determined using the empirical equations of Pauly, $Log_{10}M = 0.0066 - 0.279\ Log_{10}L_\infty + 0.6543\ Log_{10}K + 0.4634\ Log_{10}T$ (Pauly 1984), taking the mean sea surface temperature as 28.6 °C. The Pauly's empirical model for estimating natural mortality has been widely applied in crustacean studies, e.g. *Macrobrachium equidens* (Dana 1852) (Nwosu 2008), *Macrobrachium völlenhovenii* (Herklots 1857) (Etim and Sankare 1998; Nwosu and Wolfi 2006), *Portunus segnis* (Forskal 1775) (Safaie et al. 2013), and *Xiphopenaeus kroyeri* (Heller 1862) (Fernandes et al. 2014). Fishing mortality (F) was obtained as F= Z-M, and exploitation rate (E) was calculated as E= F/Z (Pauly 1984; Sparre and Venema 1998).

Crab stocks were analysed with the FISAT II programme based on the relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) models of Beverton and Holt (1966).

Results

Catch status of blue swimming crabs

The number of crab fishing gear used in Lasongko Bay from 2006 to March 2014 increased rapidly by 475.09%, from 2,670 units in 2006 to 15,355 units by April 2014 (Table 1). The type of crab fishing gear in Lasongko Bay also changed, from the predominant gillnets in 2006 to traps in 2014. From 2006 to 2014, the number of gillnets used to catch crabs fell by 40.50%, while the number of traps increased by 600.09 %. The number of crab fishermen in these waters decreased by 17.26%. The number of crab fishermen in the villages of Lolibu and Wajogu dropped dramatically, whereas it increased in Batubanawa village.

Blue swimming crab catches

In terms of catch, the number of male crabs obtained during each sampling period in Lasongko Bay ranged from 20 to100 individuals, weighing 1.69-8.38 kg, and female crab numbers ranged between 25 and 86 individuals weighing 2.18-7.40 kg. The combined numbers of male and female crabs ranged from 45 to 186 individuals weighing 3.87-78 kg. The highest number and weight of crabs were caught in May, while the lowest number and weight were recorded during September (Fig. 2). The number and weight of male and female crabs caught from May to September declined, whereas from September to January, they were observed to increase.

Table 1. Types and number of crab fishing gear and fishermen in each village in Lasongko Bay for 2006 and 2014.

Village	Number of gillnets (piece)		Number of traps (unit)		Number of Fishermen	
	2006[a)]	2014	2006[a)]	2014	2006[a)]	2014
Lakudo	35	6	-	-	9	2
Wanepa-Nepa	-	14	-	-	-	4
WongkoLakudo	39	18	-	-	13	7
Matawine	-	3	-	1100	-	13
NepaMekar	-	61	-	-	-	7
TelukLasongko	-	18	-	660	-	18
Mone	23	3	436	1102	19	17
Wajogu	156	20	-	1172	50	12
Lolibu	167	148	1713	5504	167	63
Boneoge	-	6	-	75	-	3
Batubanawa	101	13	-	5432	33	41
Total Number	521	310	2149	15045	291	187
Change (%)	- 40.50		+ 600.09		- 17.26 %	

Note: [a)]Hamid (2011), 1 piece cut into 9-12 unit gillnets; -: decreased; +: increased

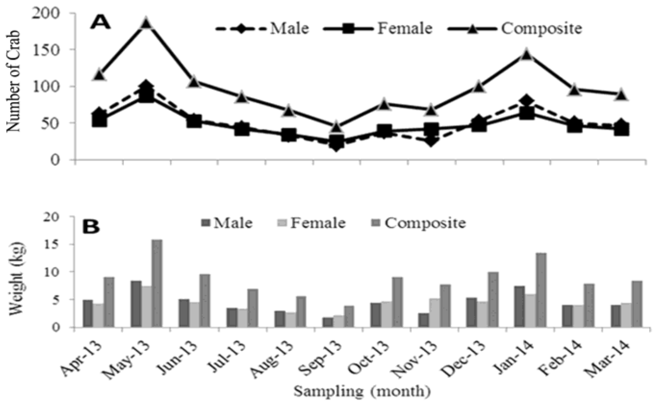

Fig. 2. The total number (A) and weight (B) of crabs during each catch sampling in Lasongko Bay from April 2013 to March 2014.

Daily total crab catches in Lasongko Bay from April 2013 to March 2014 ranged between 10.6 and 573.3 kg, with the average ranging between 94.3 and 272.5 kg; the catches were highest in July and lowest in October. Daily total crab catch differed significantly ($p< 0.05$) between the different months (Table 2). The total crab catch were estimated at 44,194.56 kg (Hamid 2011) in 2006 and at 66,926.6 kg from April 2013 to March 2014, an increase of 51.44% over the period. The increased catch were not proportional to the increase in the number of fishing gear (around 475%) over the same period of time, indicating that crab stocks have been overfished.

Table 2. Daily and monthly crab catches in Lasongko Bay from April 2013 to March 2014.

Month	Monthly catch (kg)	Daily catch (kg)		
		Mean	Highest	Lowest
April 2013	5605.2	186.8[c]	340.8	10.6
May 2013	6584.5	212.4[bc]	354.3	126
June 2013	7976.4	265.9[a]	573.3	136.7
July 2013	8445.8	272.5[a]	366.8	172.3
August 2013*)	3429.3	174.75[c]	231.4	63.9
September 2013	3893.0	129.8[d]	201.7	91.2
October 2013	2922.4	94.3[e]	153.9	0
November 2013	4010.7	133.7[d]	190.1	83.1
December 2013	6014.4	203.7[bc]	306.3	114
January 2014	5835.4	194.4[bc]	270.6	136.3
February 2014	6214.8	222.0[b]	297.5	171.5
March 2014	5994.7	193.4[bc]	244.4	128.5
East season **)	5989.0 ± 2070.4[a]	206.5±55.5[a]	573.3	10.6
West season	5165.4 ± 1365.5[a]	194.4±54.8[a]	306.3	0

Data compiled from the diaries of three crab meat processors in the Lasongko Bay period from April 2013 until March 2014; Numbers in the same column with the same letter show no significant difference ($p> 0.05$); *)Crabs were caught for only 19 days; **):East season occur from April to September, while the west season occur from October to March.

Population dynamic parameters of blue swimming crabs

The von Bertalanffy growth coefficient (K) of crabs (males and females pooled) in Lasongko Bay, as analysed by FISAT II, was 0.69 year^{-1}, and the theoretical infinite carapace width (CW∞) was 173.04 mm. Total mortality (Z) of crabs computed based on length-converted catch curve was 3.42 year^{-1} (Table 3 and Fig. 3).

The exploitation rate of crabs in these waters was 0.75, indicating that they were overfished, and the natural mortality of the crabs in Lasongko Bay was lower than their fishing mortality, giving another indication that crab stocks in these waters have been overfished, as natural mortality and fishing mortality were not balanced with the exploitation rate (E) >0.523.

Table 3. Population dynamic parameters and the exploitation rate of crab in Lasongko Bay from April 2013 to March 2014.

Population parameters	Unit	Value
Carapace witdh infinitive (CW∞)	mm	173.04
Von Bertalanffy growth coefficient (K)	year^{-1}	0.69
Total mortality (Z)	year^{-1}	3.42
Natural mortality (M)	year^{-1}	0.87
Fishing mortality (F)	year^{-1}	2.55
Exploitation rate (E)	year^{-1}	0.75
Size at first capture (CWc)	mm	105.11
Theoretical age (t_o)	year	-0.844

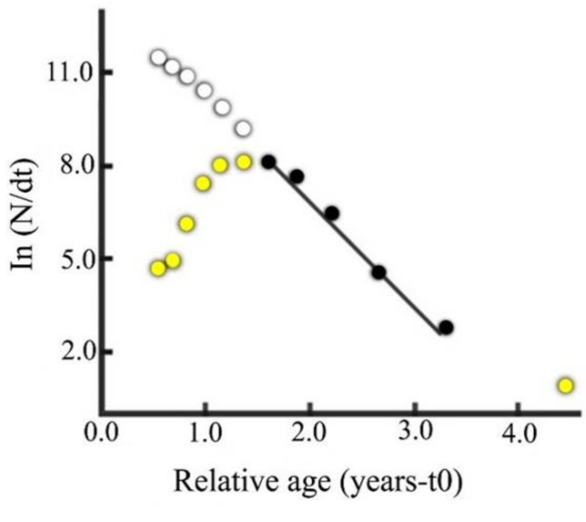

Fig. 3. Length-converted catch curve for calculating total mortality of the blue swimming crab, *Portunus pelagicus* (male and female pooled) in Lasongko Bay from April 2013 to March 2014.

Stock status of blue swimming crabs

The results of the analysis of Y'/R indicated an increase in the size of the first capture (CWc) and increases in the maximum exploitation rate (E_{max}), optimum exploitation ($E_{0.5}$), and current exploitation ($E_{0.1}$) in Lasongko Bay. However, Y'/R crabs increased in sizes only up to 105.11 mm CWc, while at 113.95 mm CWc decreased (Table 4 and Fig. 4). Without fishing, an increase in the size of the first capture can decrease the value of B'/R from the initial biomass. The maximum (E_{max}) and optimum ($E_{0.5}$) exploitation rates of crabs were 0.83 and 0.39, respectively (Table 4). The analysis of Y'/R indicates that the values of Y'/R and B'/R of crabs in Lasongko Bay are sensitive to changes in carapace width and fishing intensity.

Table 4. The exploitation rate, relative yield per recruit (Y'/R), and relative biomass per recruit (B'/R) for three sizes of the first capture (CWc) in Lasongko Bay.

Population parameter	Size of the first capture (CWc)		
	97.20 mm	105.11 mm	113.95 mm
CWc/ CW∞	0.56	0.61	0.66
M/K	1.261	1.261	1.261
$E_{0.10}$	0.67	0.71	0.81
$E_{0.50}$	0.38	0.39	0.41
E_{max}	0.76	0.83	0.91
Y'/R	0.056	0.063	0.059
B'/R	0.130	0.091	0.038

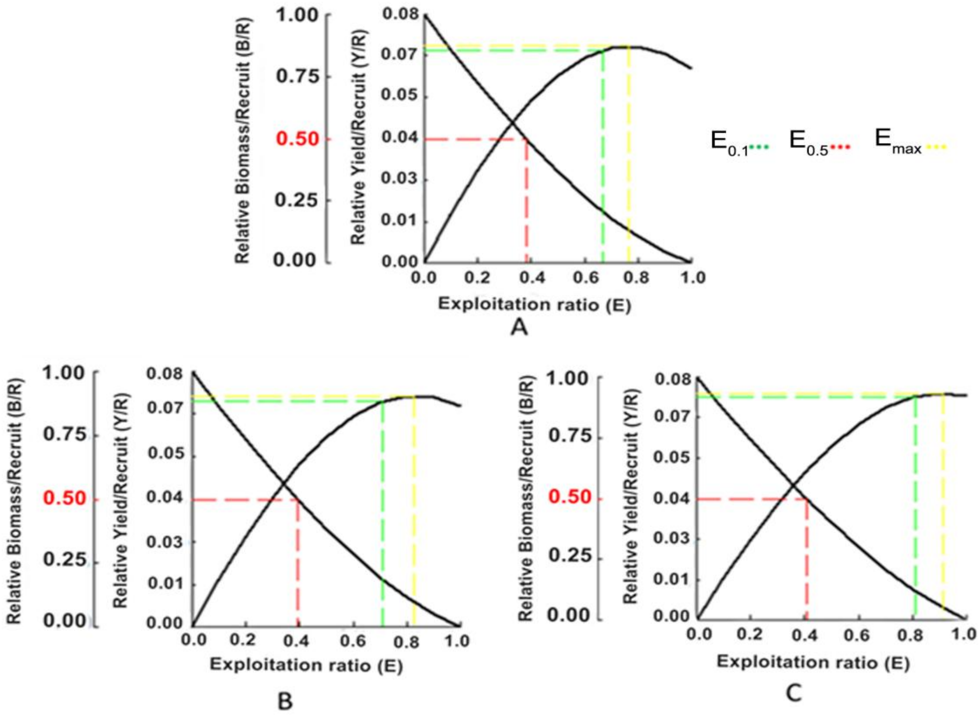

Fig. 4. Exploitation rate, relative yield per recruit (Y'/R), and relative biomass per recruit (B'/R) at CWc of 97.20 mm (A), 105.11 mm (B), and 113.95 mm (C) in Lasongko Bay.

Fig. 4B shows that if the size of the first capture (CWc) turned into 105.11 mm the growth rate would change; the relative MSY would increase by 12.5% to 0.063 and E max increased to 0.83 year^{-1}, with $E_{0.1}$ and $E_{0.5}$ at 0.71 year^{-1} and 0:39 year^{-1}, respectively. In contrast, biomass per recruitment would drop to 0.091 or 9.1% of the initial biomass. When CWc increased to 113.95 mm (Fig.4C), $E_{0.1}$, $E_{0.5}$ and E_{max} would also increase to 0.81 year^{-1}, 0.41 year^{-1}and 0.91 year^{-1}, respectively. As a consequence the MSY would decrease to 0.059, with biomass per recruitment at 0.038 (or 3.8% of the initial biomass).There are differences in body size (carapace width and weight) and sex ratio between data collected in 2006 and in 2013 at the shallower stations (Table 5). By comparing the two sampling periods, the body size of both male and female seemed to get smaller and fewer in numbers. Both sexes were more affected by fishing pressure in shallow than in deeper locations. Fishing ground of the crab in Lasongko Bay has been concentrated in the shallow waters.

Table 5. Mean body size and sex ratio of crabs in Lasongko Bay during October to December 2006 and 2013.

Location	2006[a,b)]			2013		
	Number of crab	Carapace width (mm)	Body weight (g)	Number of crab	Carapace width (mm)	Body weight (g)
Shallow (100-350 cm):						
Male	1003	112.2	99.72	73	109.6	97.4)
Female	1049	113.6	101.36	48	108.8	88.95
Sex ratio	0.96:1			1.46:1		
Ovigerous female	103	119.5	126.33	23	121.5	138.90
Deeply (>500-1200 cm):						
Male	145	123.2	116.5	17	112.6	97.58
Female	195	120.5	109.5	20	117.9	113.86
Sex ratio	0.74:1			0.70:1		
Ovigerous female	43	125.1	147.37	8	125.0	132.63

Note: [a,b)]Hamid et al. (2006) and Hamid (2011)

Discussion

Daily total crab catches in Lasongko Bay were found to vary between sampling periods (see Table 2). These findings are identical to those reported in the waters of Sarawak, Brebes, Pati and East Lampung, namely the crab catches fluctuated between periods and cycles of the moon (Ikhwanuddin et al. 2009; Sunarto 2012; Ernawati 2013; Zairon et al. 2014a). The peak season of crab fishery in Lasongko Bay was in May to July, while the low season was from August to November coinciding with the end of the dry season. The water temperature, daily temperature fluctuations, and salinity of Lasongko Bay from August to November were higher than during the remaining 8 months (from December to July). This suggest that, under such conditions, crabs may become less active and immerse themselves in the substrate, making it difficult to catch them and thus causing the observed decline in catches. A similar phenomenon has been observed when water temperatures are low in the winter; crabs become inactive, immersing themselves in the substrate (Sumpton et al. 1989) and migrating to deeper areas (Kangas 2000). Most fishermen in Lasongko Bay do not catch crabs during this low season.

The total natural and fishing mortality of crabs in this study were lower than those recorded from previous studies, i.e. such as those in South Karnataka coast, India: 2.20 and 4.10 $year^{-1}$ (Dineshbabu et al. 2008), in Bangkalan coast, Indonesia: 3.67 and 13.69 $year^{-1}$ (Muhsoni and Abida 2009), in Oman coast, Oman: 3.15 and 4.7 $year^{-1}$ (Mahanna et al. 2013), and in Arabian sea, Pakistan: 1.684 and 2.915 $year^{-1}$ (Afzaal et al. 2016), but was higher than those reported from Brebes coast, Indonesia for fishing mortality: 0.98 $year^{-1}$ (Sunarto 2012). The differences in both natural and fishing mortality of the crab might be related to the level of fishing pressure and habitat conditions, as well as the differences in methodology for calculating the crab mortality. The crab exploitation rate in Lasongko Bay was higher than those of Brebes coast (Sunarto, 2012) and Bangkalan coast (Muhsoni and Abida 2009). The maximum (E_{max}) and optimum ($E_{0.5}$) exploitation rates of crabs in Lasongko Bay were higher than those in Kung Krabaen Bay, Thailand (Kunsook et al, 2014), whereas the rate of exploitation ($E_{0.1}$) was similar to the present study.

K and t_0 values found in this study (male and female data were pooled) were lower than those of male: 0.93 $year^{-1}$ and -0.963 year, but were relatively similar with those of female: 0.68 $year^{-1}$ and -0.844 year, as reported in the study of Hamid and Wardiatno (2015). The K value in the present study was also smaller than others at several locations in Indonesia, such as in the Bone Bay: male 1.27 $year^{-1}$, female 1.08 $year^{-1}$ (Kembaren et al. 2012), Pati coast: male 1.26 $year^{-1}$, female: 1.13 $year^{-1}$ (Ernawati 2013), and Pangkep coast: male 1.2 $year^{-1}$, females 1.5 $year^{-1}$ (Ihsan et al. 2014). The K values of blue swimming crab population in other countries were higher, such as in Thailand: male 2.75 $year^{-1}$, females 1.13 $year^{-1}$ (Kunsook et al. 2014), in India: males 1.3 $year^{-1}$, females 1.4 $year^{-1}$ (Dineshbabu et al. 2008), in Oman: male 1.85 $year^{-1}$and females 1.68 $year^{-1}$ (Mehanna et al. 2013), in Pakistan: 1.70 $year^{-1}$ (Afzaal et al. 2016).

The CW_∞value in the present study was higher than those in the Bone Bay: male 159.0 mm, female 154.0 mm (Kembaren et al. 2012), but was smaller than those in Pati coast: male 185 mm, female 187 mm (Ernawati 2013) and Pangkep coast for female 186.38 mm (Ihsan et al. 2014). By comparing the crab population in other countries, the CW_∞value of the crab population in Lasongko Bay was higher than those of population in India: male 116.9 mm, female 170.0 mm (Dineshbabu et al. 2008), but was smaller than those in Iran: male 191.0 mm, female 185.0 mm (Safaie et al. 2013) and in Pakistan: 178.5 mm (Afzaal et al. 2016). The low K value (less than 1) indicates slow growth rate (King 1995; Sparre and Venema 1998). The t_0 value in this study was smaller than in Pakistan waters (Afzaal et al. 2016). Negative value of t_0 indicates rapid growth at the juvenile stage of the crab (King 1995; Sparre and Venema 1998; Afzaal et al. 2016). The exploitation rate of blue swimming crab in Lasongko Bay is currently 0.75 (see Table 4); based on the analysis of the relative yield per recruit (Y'/R) with the size of the first capture of 105.11 mm (CWc 50 %), the optimum exploitation rate ($E_{0.5}$) is 0.39. The current exploitation rate ($E_{0.1}$) is 0.71 (see Table 4 and Fig. 4).

Based on this information, crab stocks in Lasongko Bay have been overfished at a rate of 192.30 % of the optimum exploitation rates ($E_{0.5}$) and 105.63 % of the current exploitation rate of crabs ($E_{0.1}$). The reported rates of exploitation of crabs from other waters worldwide also indicate overfishing (Kamrani et al. 2010; Kembaren et al. 2012; Sunarto 2012; Mehanna et al. 2013; Safaie et al. 2013; Kunsook et al. 2014; Afzaal et al. 2016). In some waters in Indonesia, the crab stocks have also been overfished (Muhsoni and Abida 2009; Kembaren et al. 2012; Ernawati 2013; Ihsan et al. 2014; Hamid and Wardiatno 2015), with Brebes waters in Java being an exception (Sunarto 2012).

Five indicators of critical crab stocks were introduced including high fishing mortality rate, an exploitation rate exceeding the rate of optimal exploitation (E> 0.5) (Gulland 1971), smaller size of adult female crabs, the increase in ovigerous female crabs being caught, and the decrease in average fecundity (Kunsook et al. 2014). Based on these indicators and some of the previously described findings, the status of crab stocks in Lasongko Bay is currently considered to be critical. The status of these crab stocks is likely to become more critical if there is no immediate management efforts. Patterson (1992) stated that the exploitation rate should be less than 0.4 for sustainable use of aquatic resources. In the present study, several indicators suggest that crabs in Lasongko Bay have been overfished, i.e. the increase in the number of fishing gears which was not proportional to the increase in catch, changes in sex ratio and the reduced sizes of crabs in a shallow location, and the decrease in numbers of ovigerous female crabs in 2013 (see Table 5). In Lasongko Bay, shallow locations (100–350 cm depth) and seagrass beds were more exploited than deeper locations (500–1200 cm depth).

Finding by Hamid and Wardiatno (2015) showed that females are more affected than males due the fishery activities in the shallow by considering the fishing mortality value. The change in sex ratio and size might be caused by high-intensity catches and changes in the predominant types of fishing gear from gillnets to traps, as previously described (see Table 1). This conclusion is also supported by the results of previous studies by Johnston et al. (2011) and Kunsook et al.(2014). Traps have been the dominant crab fishing gear in Lasongko Bay since 2008.

Conclusion

Currently, the crab stocks in Lasongko Bay are in critical condition due to overexploitation. Some crab management initiatives should be taken in order to protect the sustainability of crabs in Lasongko Bay, such as reducing the number of traps by up to 50% of the current total, not catching ovigerous female crabs, restricting the carapace width of crabs that may be caught to sizes >105.11 mm, and relocation of the crab fishing grounds to areas in and around the mouth of the bay.

It is crucial to issue the respective regulation and strict surveilence on catch size. In addition, there is a need to protect and rehabilitate the habitat and develop crab sanctuary areas and restocking strategies in Lasongko Bay.

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