Status of blue swimming crab (*Portunus pelagicus*) population in Southeast Sulawesi waters, Indonesia

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Abstract. One of economically important crustacean in Indonesia is blue swimming crab (BSC) that is distributed in most of its coastal waters. In Southeast (SE) Sulawesi, BSC constitutes as the most important fishery resources after shrimp and tuna due to its high demand and premium price. In the last three decades, BSC has been intensively exploited using collapsible pots, gillnets, and mini trawls in the main fishing grounds of SE Sulawesi waters although it is still categorized as small scale fishery. Recent data showed that its catch per unit effort (CPUE) has decreased from 6-11 kg trip^{-1} to be 2-3 kg trip^{-1}. This phenomenon implies that fishing mortality of BSCs is higher than that of natural mortality. Fishing activities in the entire regions of SE Sulawesi waters had reached over exploitation level. We had done some efforts in the past five years to manage the BSC resources in the region such as using crab pots with escape vents in both sides, prohibiting catch of berried females, and constituting the marine protected area (MPA) for BSC juveniles. Some recommendations for future management measures from our studies are regulating the number of allowable crab pots to be used by fishermen, prohibiting the use of unselective fishing gears such as gillnets and mini trawls, and constituting close season and areas for BSC fishing.

Key Words: blue swimming crab, bottom gillnet, collapsible pots, mortality, over exploitation.

Introduction. The blue swimming crab (BSC, *Portunus pelagicus*) is commonly found in inshore and continental shelf throughout the Indo-Pacific region (Germano et al 2006; Department of the Environment and Heritage 2006; Queensland Government 2011). Its distribution extends from the east coast of Africa across to Tahiti, northward to Japan and south to waters surrounding northern New Zealand (Department of the Environment and Heritage 2006). In Indonesia, this species is widely distributed from the western coast of Sumatera and move forward to the northern coast of Java, southern and eastern coast of Kalimantan, and southern part of Sulawesi (South Sulawesi and SE Sulawesi) up to the western part of Papua (Figure 1) (Sumiono 1997; La Sara & Astuti 2015). However, its high exploitation concentrates in the northern coast of Java, around SE Sulawesi waters, Riau Island waters, and northern and southern coasts of Sumatera (La Sara et al 2016a). Population of BSC in all those areas have been experiencing heavy presurre of exploitation due to its high demand of concumers and high price (Hisam et al 2018).

The BSCs in SE Sulawesi waters are generally found in Lasongko Bay, Tiworo Strait, Kolono and Moramo waters, around Kabaena Island, western part of Bombana, Toronipa of southern of Konawe, and North Buton waters. Those locations are mainly fishing ground of BSCs contributing up to 60% of BSCs total production (La Sara et al 2016b). Its production in 2005 was about 2,000 tons and it increased to be about 4,000 tons in 2012 (La Sara et al 2017). BSC resources have been contributing to social and economic welfare of local community as well as local government revenue through providing livelihood to approximately 3,500 fishermen and 1,500 labors at several mini

plants. However, there is an apprehensive regarding sustainability of this population which had been commercially exploited since the last three decades by fishermen organized by several exporters of BSC. Those exporters also built mini plants close to fishing ground of BSC (La Sara & Astuti 2015). Generally, fishermen use unselective fishing gears of collapsible pots, bottom gillnets, and some mini trawls to catch BSC leading to drastically decrease of its population (La Sara et al 2016c). Our previous studies showed that BSC caught at several fishing grounds in SE Sulawesi had a declined carapace width (CW) to be < 6 cm, decreased in the CPUE, and fishing ground moved afield from its initial habitats (La Sara et al 2016b, 2016c, 2016d).

In this present paper, we overview findings on BSC fisheries studies that was conducted in SE Sulawesi to reveal the present condition of BSC population in the region. The objective of this paper is to supply scientific information regarding the status of BSC population in this area to be used by (1) local government in order to implement policies and regulation regarding this species, and (2) BSC exporters to ban fishermen from catching undersizes BSC.

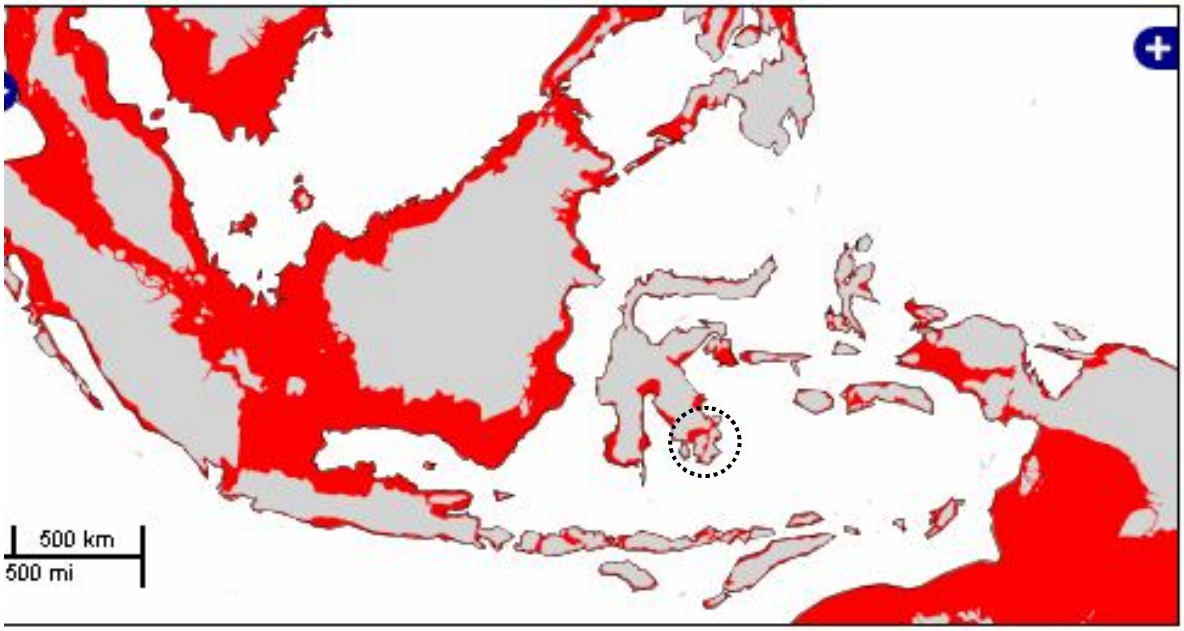

Figure 1. Map of BSC distribution around Indonesia waters (red color is fishing ground of BSCs; dash circle is SE Sulawesi waters) (FAO 2013).

BSC fishing gears and production. BSC is exported as frozen crab or frozen crabmeat particularly to United States and other countries. The Indonesian BSC production export to United Stated reached 50% of total production (Marketing Director of Product Competitiveness 2017; Gofar 2017), with BSC from SE Sulawesi contributed around 8.8% (Nuraini 2014). High market demand of BSC has been leading to intensive exploitation of the resources using crab pots, bottom gillnets, and some mini trawls although few fishermen also use fish line. The first two gears are stationary gears which are commonly used by fishermen (La Sara et al 2016a).

Crab collapsible pots (Figure 2) is operated by put fresh fish baits inside and placed in relatively shallow coastal waters of < 5 m, whereas bottom gillnets (Figure 3) are operated in the deep waters of > 10 m parallel to coastal line. Mini trawl (Figure 3) is a dynamic and very destructive fishing gear due to its ability to catch almost all species at the sea bottom. This gear is operated by hauling it with a motor boat at the water depth of > 10 m thus able to cover wide area of coastal waters. All those fishing gears are unselective (La Sara et al 2016d, 2016e, 2017). The data of fishing gears used by fishermen in SE Sulawesi had been reported by USAID (2014) (Table 1). There are two boats types used by fishermen to catch BSC, without machine (< 1 GT) and with outer machine of 1-2 GT and 5 GT boats. In 2013-2014, there were around 1,300 boats of less

than 1 GT, 975 boats of 1-2 GT and 100 of 5 GT boats. The latter is operated by fishermen in the deep waters (> 20 m) for bottom gillnets.

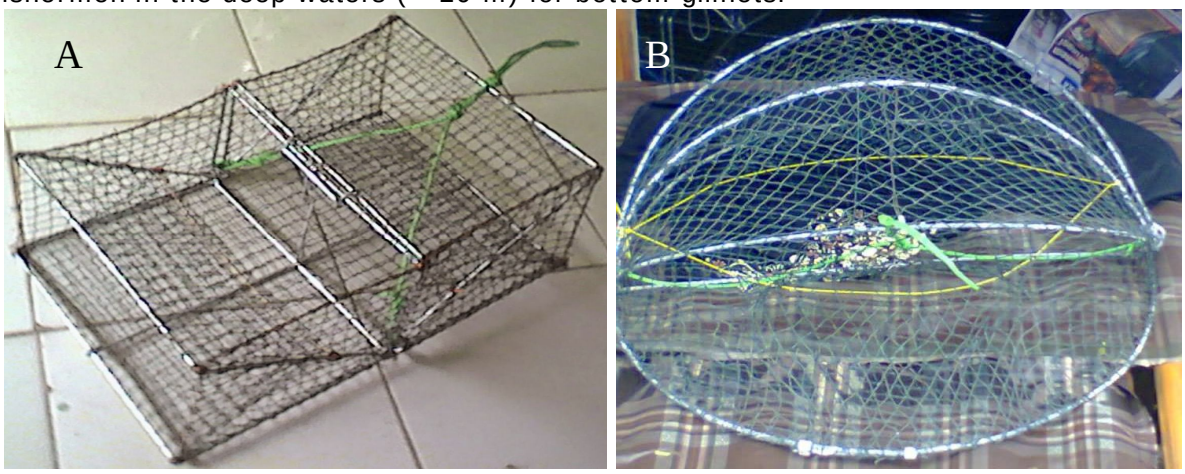

Figure 2. Collapsible pots are commonly used by fishermen in SE Sulawesi waters (A. rectangular type; B. circular type).

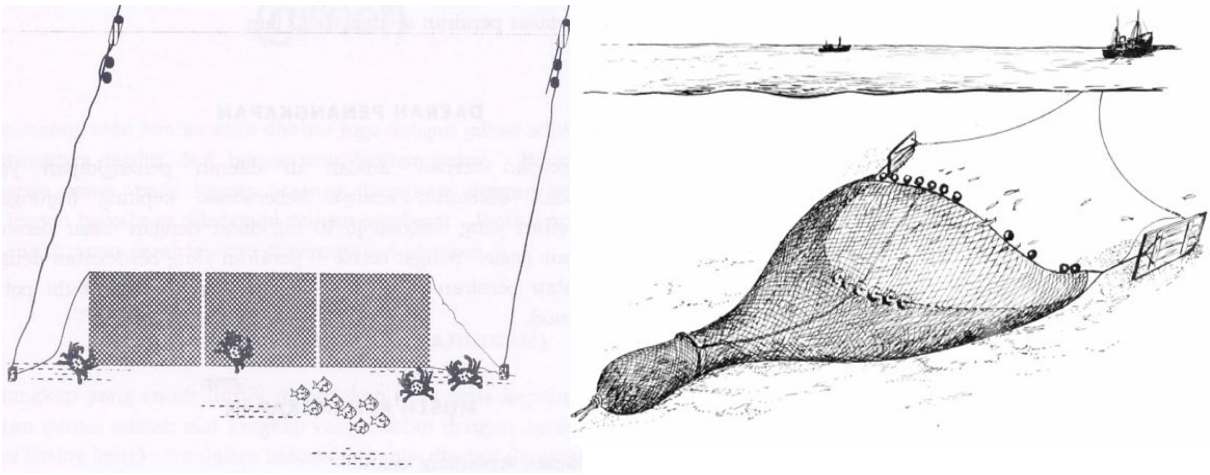

Figure 3. Bottom gillnet (left) and mini trawl (right) used by fishermen in deep sea waters in SE Sulawesi.

Table 1

Type of fishing gears and fishermen of BSC in SE Sulawesi waters (USAID 2014)

No.	*Fishing gear*	*Water depth (m)*	*Total fishermen*	*Fishermen percentage (%)*
1	Fish line	2-5	280	3
2	Bottom gillnet	> 5-30	1.250	46
3	Collapsible crab pot	1-5	3.500	50
4	Others	2-5	< 100	1

Exploitation rate and population status. Studies on BSC intensive exploitation and population status were the main concern to scientists in SE Sulawesi to determine appropriate management measures in ensuring BSC population sustainability. Study by Muchtar et al (2017) found that BSC total mortality (Z) rate in SE Sulawesi had reached 2.30 year^{-1}. Fishing mortality (F) of 1.12 year^{-1} contributed 65.65% to total mortality (Z) with exploitation rate (E) of 0.66 year^{-1} indicating that BSC population had reached over exploitation. Study of BSC population in Tiworo strait found that the mortality (Z, M and F) of males was higher than that of females (Table 2). Of about 33.3% was contributed from M for Z males and 97.5% for Z females (La Sara et al 2017).

The BSC males and females have different preference to habitats during maturity stage. BSC males generally occupy intertidal waters with depth of < 10 cm, whereas BSC females, particularly of those gonad mature and berried females, move to high saline sea waters with depth of > 10 cm. Therefore, based on those preferences, the exploitation rate of males and females BSC is different (La Sara et al 2016d). For example, Muchtar et al (2017) found that Z of males was higher (2.15 $year^{-1}$) compared to females (1.21 $year^{-1}$), whereas F of males and females was 1.12 $year^{-1}$ and 0.57 $year^{-1}$, respectively. This study also found that F of males contribution to Z was 52.89% which was higher than that of female which was 47.11% (Muchtar et al 2017). Similar data trend of BSC population was found in Tiworo Strait (Table 2) (La Sara et al 2017). The recent study conducted in Aru Islands waters of Maluku showed much higher exploitation rate (E) of 0.76 which was contributed from F of 3.73 $year^{-1}$ and Z of 4.94 $year^{-1}$ (Kembaren & Surahman 2018).

Table 2

Total mortality (Z), natural mortality (M), and fishing mortality (F) of male and female BSCs in Tiworo Strait of SE Sulawesi, Indonesia

No.	*Parameter*	*Male*	*Female*
1	Z	4.11	0.79
2	M	1.37	0.77
3	F	2.74	0.02
4	E	0.67	0.03

It has been understood that high exploitation of BSC occurs in the shallow water of 1-5 m which is occupied by BSC males at all stages of development from juvenile, adult to mature, while BSC female is only during juvenile and adult stages. The berried and gonad mature females move to the sea water with high salinity of > 30 ppt and water depth of > 10 m (La Sara et al 2016a). Other studies revealed that the deeper of water the higher of BSC females catch in the respective of Makassar Strait (Adam et al 2006) and Demak coastal waters (Prasetyo et al 2014). However, some studies showed that the Z of females was lower than that of males (Dineshbabu et al 2008; Sawusdee & Songrak 2009; Kunsook et al 2014). It is common to observe that male of crab species has a bigger size than female and this condition led to most vulnerable on fishing activities. King (1995) stated that generally M values on both sexes were higher due to predation.

Efforts in sustaining the BSC population. Collapsible pots and bottom gillnets are common fishing gears used by fishermen which have serious negative impact on BSC population. It leads to BSC population over exploitation which was characterized by (1) low BSC CW (2-5 cm), (2) low CPUE at 2-3 kg $trip^{-1}$ (1 trip = 1-2 days) (La Sara et al 2016b), (3) fishing grounds moving further afield (La Sara et al 2016b), (4) SPR of 13-14% (La Sara & Astuti 2015; La Sara et al 2016c, 2016d), and (5) dissapearing population in several coastal waters (La Sara et al 2016b). Moreover, the decreasing of BSC population is doubled by either intensive exploitation or destruction of their corresponding habitats such as mangrove, seagrass and coral reef serving as their feeding ground and shelter for BSC juveniles (La Sara et al 2016d, 2016e). Similar condition of BSC population was found in Madura waters of East Java (Muhsoni & Abida 2009), East Lampung waters *(*Zairion et al 2014), coastal waters of northern Java (Java sea) (Ernawati et al 2014), and others Central Java waters (Budiarto 2015; Tama et al 2017), and northern Lamongan of East Java (Rahman et al 2019).

In the ecological point of view (Kunsook et al 2014a; 2014b), threatened of BSC population sustainability in those waters will rise problems to the food webs and structure of trophic level in the coastal and marine ecosystem (Sukumaran & Neelakantan 1997; Wu & Shin 1997; Kunsook et al 2014b). Exploitation of mangrove forest (Government of South Australia 2012) and coral reefs as well as illegal fishing using bom and cyanide are expected to increase a compensation to BSC catch decrease. Another negative impacts are problems related to social, economy and environment. Loss of livelihood for

fishermen and coastal community (i.e., pickers in the mini plants) and decreasing fishermen income will affect local government revenue and will rise up other social problems such as urbanisation (Kunsook et al 2014b). Loss of animal protein source which in turn will impact the health of coastal community thus low quality of human resources in those regions is another social problem that may rise from decreasing population of BSC. Furthermore, the problems in the BSC fisheries may also affect the national government, industries (mini plants and exporters of crab meat), and global consumer supply (United State, Europe, Japan, Singapore, etc).

Several recommendation have been suggested to sustain BSC population including using selective crab pot attached with escape vents in both sides (La Sara et al 2016b, 2016e). Muskita et al (2015) found that harvest control and knowledge of aquatic ecosystem in Tiworo Strait, SE Sulawesi may help in sustaining BSC population. The effort of regulating BSC fishing and protecting its habitat are facing big constraints particularly because the data of BSC potential and its distribution are not available. To overcome those problems, studies to support the sustainability of BSC regulation such as mapping BSC fishing ground is required to obtain more comprehensive picture on their population and distribution for a better management (La Sara & Astuti 2015; La Sara et al 2016a, 2016b).

Formulated minimum legal size (MLS) and fishing gear selectivity. The first effort to be conducted is identifying the gonad growth according to CW sizes of both sexes to find out the size of CW at first gonad maturity. Our study showed that BSC first spawning occured when their CW was ≥ 10 cm (La Sara et al 2016d, 2016e). This finding is used as a base to formulate the MLS of CW. Further more, MLS of this CW is the minimum size of "jumbo lump" in crab market. The meat of BSC at this CW size is considerably bigger than smaller CW and therefore, meat processing at mini plant is much faster thus low labor cost (La Sara & Astuti 2015; La Sara et al 2016a, 2016b).

The MLS of CW of ≥ 10 cm was used to design a selective fishing gear for BSCs where CW smaller than the MLS (< 10 cm) will have opportunity to escape from the gears back into the sea. The result showed that the collapsible pot equipped with escape vent of 3.5 cm x 5.0 cm in both sides had high percentage of BSC of > 10 cm caught (±85% from total caught) (La Sara et al 2016e). Prior to Indonesia implementing MLS of BSC, Philippines had prohibited trade of BSCs that are less than 10.20 cm CW (Germano et al 2006; PACPI 2015). In Queensland, Australia, the MLS of BSC allowed to be caught was 11.5 cm (Queensland Government 2011), whereas in Vietnam, MLS of BSC is 10 cm, but no law enforcement implementation yet (La Sara et al 2016a, 2016b, 2016e). In Pattani coastal waters of Thailand, female BSC was estimated to reach sexual maturity at 9.97 cm CW (Hisam et al 2018), whereas others studies showed that it was at 9.50 cm CW in Malaysia (Ikhwanuddin et al 2009) and at 8.90 cm CW in Pakistan (Rasheed & Mustaquim 2010). The highest CW size of sexual maturity of 11.99 cm was found in Aru Islands of Maluku (Kembaren & Surahman 2018).

In 2015-2016, we conducted a study on biological reproduction of BSC to find out a practical and easy to operate selective fishing gear for BSC. We used 1.5, 2.0, and 3.0 inch mesh size net that covering main frame of collapsible pot and the collapsible pot using escape vent (Muskita et al 2015; La Sara et al 2016a). The result showed that collapsible pot with mesh size of covered net of 3.0 inch on main frame was more selective than other mesh sizes. The BSC retained in the crab pot was only 1.54%, whereas the BSC retained in the crab pot with escape vent was 9.29% (La Sara et al 2016a).

Returning berried female. Providing information to all fishermen around Tiworo Strait and others areas in order not to catch berried females was continuously conducted since 2012. They have to be returned to the sea in order to let them have the opportunity to spawn, minimum once in their lifetime. This effort is aimed to sustain BSC population and in accordance with the Regulation of the Minister of Marine Affairs and Fisheries No. 1/2015 (La Sara & Astuti 2015; La Sara et al 2016b; Basri et al 2017).

Commitment of APRI and the Government. In 2014, the local government of SE Sulawesi officially established an organisation named "Data Management Committee of BSC" (La Sara et al 2016b). A study conducted in 2013-2014 came out with the conclusion of MLS for BSC to be caught is ≥ 10 cm of CW (La Sara et al 2016b, 2016e).

In February 2014, APRI, a BSC national exporter association in Indonesia, agreed and committed to implement to all its members and related mini plant that MLS of BSC is ≥ 10 cm. The agreement was signed by 12 members of APRI. According to APRI, the implementation of MLS ≥ 10 cm of CW actually is able to maintain: (1) the BSC population sustainability, (2) job opportunity for fishermen and pickers in the mini plants, and (3) marketing system (export) of BSC meat (La Sara et al 2016b). The national government has declared the Regulation of Minister of Marine Affairs and Fisheries No. 1/2015 regarding prohibiting the catch of BSC < 10 cm of CW and berried females.

Mapping fishing ground and nursery ground. A study was conducted to map fishing and nursery ground of BSC in Tiworo Strait (Muskita et al 2015). Stock assessment at fishing ground of BSC was also conducted to regulate its fishing effort based on spatial and temporal distribution (La Sara et al 2017). Location of each nursery ground which generally found in intertidal zone adjacent to mangrove area was decided to be a marine protected area (MPA) for BSC (Muskita et al 2015; La Sara et al 2016d). Its management scope was formulated together with local community in a focus group discussion (FGD). The regulation of MPA consisted of (1) fishing efforts of BSCs or other related activities are not allowed in the MPA, (2) the objective of MPA management is to give opportunity of BSC juveniles to grow to mature sizes, and (3) the split over of BSC mature sizes from the MPA is allowed to be caught by fishermen (Muskita et al 2015).

Conclusions. Due to premium price of BSC and high demand of consumers either in domestic or global markets lead to intesive exploitation all year round. Fishing of BSC has been using unselective fishing gears of collapsible crab pots, bottom gillnets, and some mini trawls which catch all sizes of BSCs particularly juveniles. This practice threatenes the sustainability of BSC population. BSC population characteristics study showed that the status of BSC population in SE Sulawesi was over exploitation (E > 0.5).

Sustaining BSC population can be achieved through maintain and protect its habitat, prohibit illegal fishing, and implement the regulations. Several regulations produced from our studies in BSC fishing include prohibit the catch BSC < 10 cm of CW, release catched berried females, and prohibit the catch of BSC at nursery ground or MPA. Also, crab pots with escape vent of 3.5 cm x 5.0 cm attached in both sides must be used to ensure that only BSC > 10 cm of CW is caught by fishermen. The others action recommended to sustain BSC population are formulating catchability of fishing gears, dimension and numbers of fishing gears used, data on spatial and temporal catch production to formulate management policy for sustainable BSC fishing. A hatchery for seeds production constitutes an urgent action for restocking and for BSC cages cultivation.

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