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## Research Article

# Appropriate Escape Vent Sizes on Collapsible Crab Pot for Blue Swimming Crab (*Portunus pelagicus*) Fishery in Southeast Sulawesi Waters, Indonesia

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## Abstract

**Background and Objective:** Blue Swimming Crab (BSC) fishery in Southeast Sulawesi faces huge pressure as indicated by smaller Carapace Width (CW) of  $<7$  cm, small biomass of  $10\text{--}20$  ind  $\text{kg}^{-1}$ , CPUE of 2-3 kg per trip and fishing ground moving further afield. There is no study on selective crab pot for BSC had been done. This study conducted to find out the appropriate escape vent size of crab pots used by fishermen. **Methodology:** This study used collapsible crab pots equipped with escape vent in the left and right sides in order small sizes have opportunity to escape and return to the sea to grow and attain maturity. Those escape vent sizes of crab pots tested were  $4.0 \times 3.5$ ,  $4.5 \times 3.5$  and  $5.0 \times 3.5$  cm to find out only BSC of  $\geq 10$  cm CW retained in the crab pots. The BSCs of  $<10$  cm CW escaped from crab pot and gathered into "codend" which was tied in the vent. The BSCs retained in the crab pots and escaped in the codends were measured its CW using caliper, wet weighed their body using electronic balance and identified their gonad maturity and then all recorded in the data sheet. The BSC data was analyzed using "the gear selection ogive" which formulated in the mathematic equation forming sigmoid curve. **Results:** From three escape vent sizes, the crab pot with escape vent size of  $5.0 \times 3.5$  cm retained BSC at  $L_{50\%}$  was 10.74 CW while,  $L_{50\%}$  of escape vent size of  $4.5 \times 3.5$  cm and  $4.0 \times 3.5$  cm was 9.26 cm CW and 8.75 CW, respectively. **Conclusion:** The curve of gear selection ogive shows that the minimum legal size of BSC at  $L_{50\%}$  to be recommended is 10.74 cm CW which is found at the escape vent size of  $5.0 \times 3.5$  cm. This CW has already reached maturity stage and at least once producing eggs.

**Key words:** Escape vent sizes, crab pot, minimum legal size, *Portunus pelagicus*

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**Competing Interest:** The authors have declared that no competing interest exists.

**Data Availability:** All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Indonesia waters is one of Blue Swimming Crab (BSC) habitats in Indo Pacific regions as shown its wide distribution in the entire of coastal waters of Indonesia from the tip of Western Sumatera to Eastern part of Papua. The Southeast Sulawesi waters has been known as a habitat of BSC since last decades. The BSC fishery has provided a wide opportunity for employment and sources of fishermen income. The gears used by fishermen are crab pots (crab traps) and gillnets. Most of crab pots are fitted with a primary, one-way entrance point that is sized to accommodate the biggest available crabs in an area. Through this entrance point, both big and small crabs enter the crab pot without capability to escape. Unselective traps may cause unwanted BSC sizes retaining in crab pots. It was reported that *Scylla serrata*<sup>1</sup> caught by poor trap selectivity was only 32%, the remaining catches was discarded<sup>2</sup>. It is revealed that a poorly selectivity traps can perpetuate uncounted fishing mortality. Those such cases, warrant studies modification BSC traps to improve their selectivity and species enter the traps. Several studies have been done and among those studies concluded that selectivity and efficiency of crustacean traps are influenced by spatial and temporal deployment<sup>3</sup>, design and shape of traps<sup>1,4</sup>, number and type of entrances<sup>5</sup>, bite type<sup>6</sup>, presence and absence of escape vent<sup>3,7</sup> and size of escape vent<sup>8-10</sup>. Some those variables had been studied for *S. serrata* in Australian waters<sup>1,3,11</sup>.

Since, BSCs have high economic value in the local and export markets and several mini plants of crab meat processing present closely in the surrounding of BSC fishing ground that BSCs have been intensively and continuously exploited using those unselective crab pots. All sizes of BSC caught are picked out and sold to a mini plant of crab meat processing for export.

There are problems in sustaining BSC population due to it has been experiencing over exploitation as shown the following indicators: (1) Its CW size is dominated by small size of <7 cm, (2) The individual number caught and biomass per trip is few and (3) Its fishing ground is continuously narrow, limited and moving afieled from shore line<sup>12-14</sup>. Those problems of BSC fishery are increasingly complex due to data of bio-ecology are not recorded well. Therefore, its harvest control is difficult to be implemented due to unavailable of management formulation. The recent effort had been conducted to control BSC population by designing a much appropriate selective crab pot which only catches a big CW size in the crab pots (retained) while, the small CW sizes have opportunity to escape into the sea which they have been living in.

The crab pot designed is a collapsible pot and fitted an appropriate sized escape vent (exit point) at the right and left sides to greatly reduce the number of undersize crabs taken in a fisherman's catch. The studies regarding escape vent had been conducted on mud crab (*S. serrata*)<sup>3</sup>, velvet crab (*Necora pube*)<sup>15</sup>, rock lobster (*Jasus frontalis*)<sup>16</sup>, American lobster (*Homarus americanus*)<sup>17</sup>, lobster (*Homarus gammarus*)<sup>18</sup> and *S. olivacea*<sup>7</sup> but, not for BSC (*P. pelagicus*) in Indonesia waters or other ASEAN countries. This study will give a new insight to fishermen in conjunction with sustaining BSC fishery. The implementation of collapsible crab pots designed in the present study is useful particularly to maintain the BSC population, stabilize the biodiversity web in the referenced fisheries and essential to the long-term health and sustainability of the fishery and give time to recovery the BSC population. The objective of the study was to find out the appropriate escape vent size of collapsible crab pots for BSC. It is hoped that those crab pots designed only catch (retained) bigger sizes and that small crabs are systematically return to the sea in good condition and preferably as close as possible to their home waters to grow to attain bigger size and have opportunity to breed to essentially maintain its population number and sustainable in the Southeast Sulawesi BSC fishery.

## MATERIALS AND METHODS

The escape vent sizes of collapsible crab pot tested were 4.0×3.5, 4.5×3.5 and 5.0×3.5 cm operated in the three different fishing grounds of BSC of Soropia, Tinanggea and Waeputang waters of Southeast Sulawesi (Fig. 1) from December, 2013 to March, 2014. The dimension of crab pot was 36×54×19 cm and fitted with escape vent at its right and left sides (Fig. 2). Those dimensions of escape vent sizes were designed based on the result of study on population dynamic and size variation of BSC, CW in several fishing ground of Southeast Sulawesi<sup>12,13,19</sup> and Soropia coastal waters<sup>20</sup>. The effectiveness test of each escape vent size was set in 50 crab pots which were deployed in respective fishing grounds. Each escape vent size was marked and set alternate with interval of 10 m (Fig. 3). Generally, fishing grounds of BSC are found at the inshore with sandy and muddy substrate or overgrown by seagrass.

In order to know how many crab escaping from each crab pot that at each escape vent was attached a "codend net" with net length of 100 cm (Fig. 2). Each crab pot was baited with approximately the same sized chopping fish hung at the center of crab pot using a wire. Those crab pots were connected in the main plastic rope with a 5 m length of polypropylene rope and then deployed individually at the sea

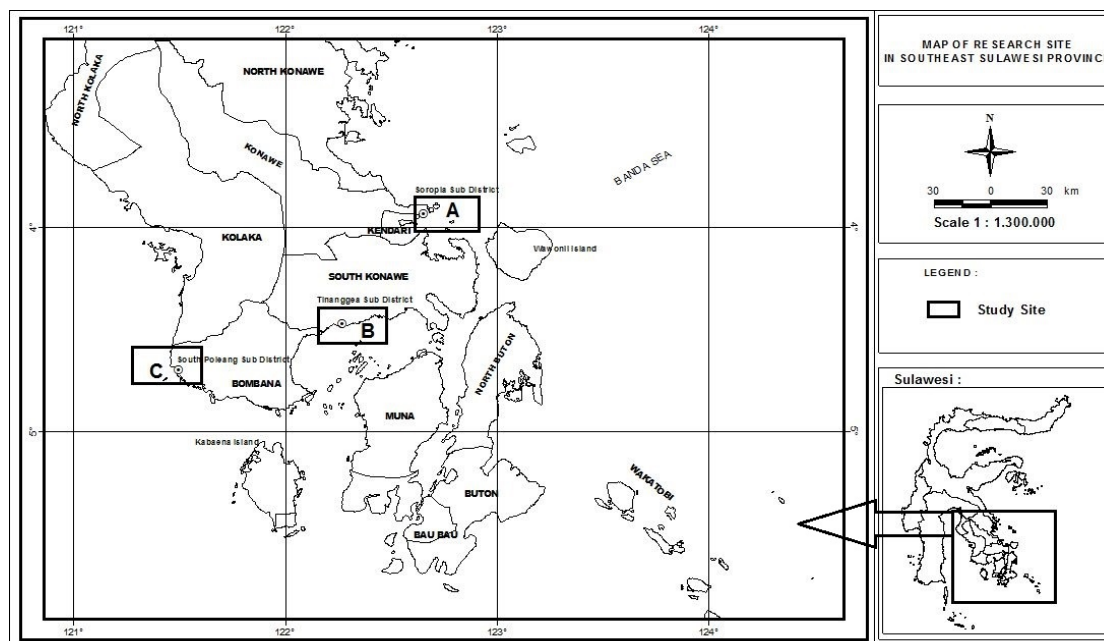


Fig. 1: Map of study sites on collapsible crab pot with escape vent sizes tested for blue swimming crab in three different fishing grounds of (a) Soropia waters, (b) Torokeku waters and (c) Waeputang waters of Southeast Sulawesi, Indonesia

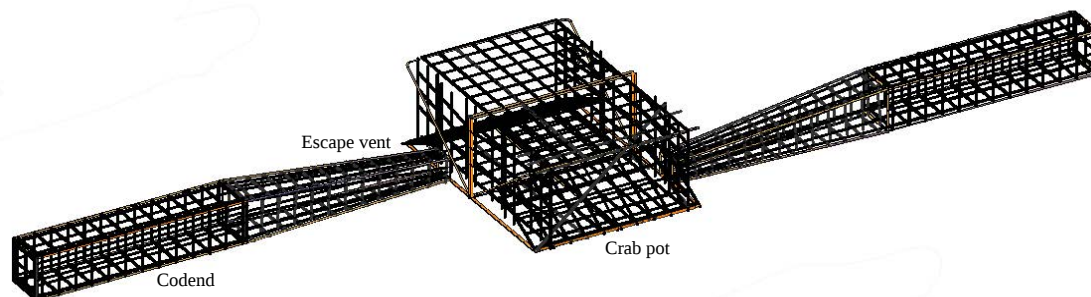


Fig. 2: Design of collapsible crab pot with escape vent and its codend in the left and right sides (to collect all blue swimming crabs escape from collapsible pot)

just at the time of flood tide. At the both tips of main plastic rope were marked with a buoy (Fig. 4). Those crab pots were retrieved at the time of ebb tide. All crab caught from both retained at the crab pot and at the codend net were measured its CW size, weighed its body weight and identified individually its gonad maturity.

Principally, the escape vent attached in the left and right sides of crab pot which could be passed by BSC have a role as a mesh size in the trawl so escape vent selectivity could be approached using the fishing gear selectivity analysis<sup>21</sup>. Method of escape vent size estimation (attached with codend) (Fig. 2) followed the method of trawl selectivity estimation. Data of each CW of BSC retained in the crab pot (Column B) and escaped (Retained in the codend) (Column C) in the

respective escape vent size were recorded in the form of CW frequency table (Table 1). The total number of BSC retained in the crab pot was stated as a group of CW of BSC retained in the crab pot (Column E). Furthermore, this data was plotted to the mean of CW interval (Column G) and finally formed a sigmoid curve reaching 1.00 (Retention 100%) at biggest CW and approaching 0.00 (Retention 0%) at smallest CW (Column F). This a sigmoid curve is called "gear selection ogive"<sup>21</sup>. The analysis procedure in Table 1 could compute a Selection Factor (SF) of escape vent to CW of BSC. Based on the SF can be established a CW which 50% of BSC retained in the crab pot ( $L_{50\%} = \text{selection factor} \times \text{escape vent size}$ ) and selection range ( $SR = L_{75\%} - L_{25\%}$ ) that explain curve slope and indicating range of selection size<sup>22,23</sup>. Both those parameters

( $L_{50\%}$  and SR) were used to compare selection curve of those three escape vent sizes tested ( $4.0 \times 3.5$ ,  $4.5 \times 3.5$  and  $5.0 \times 3.5$  cm).

## RESULTS

The results of crab pot tested using 50 U of crab pot in 3 fishing grounds in Southeast Sulawesi waters were to find out the most appropriate of escape vent size according to size of CW of BSC retained in the crab pots and escaped through escape vent of crab pots (retained in the codend) (Fig. 5).

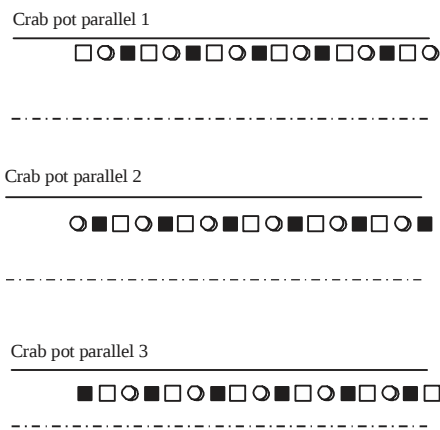


Fig. 3: Design of alternate of collapsible crab pots in the sea,  
 □: Crab pot with escape vent size of  $4.0 \times 3.5$  cm,  
 ○: Crab pot with escape vent size of  $4.5 \times 3.5$  cm and  
 ■: Crab pot with escape vent size of  $5.0 \times 3.5$  cm

**Catch composition of BSC:** The result of BSC catches from all fishing ground were pooled according to escape vent size of crab pot and then were counted its frequency at each CW interval to find out CW composition (Fig. 5).

**Escape vent selectivity:** Data of BSC caught in the crab pot (Retained) and in the codend (Escaped) were grouped according to its CW size. Each of BSC individual was grouped in the class interval of CW then counted its number. Based on number of BSC taken from each crab pot and codend in the respective interval class of CW was estimated the CW size at  $L_{25\%}$ ,  $L_{50\%}$  and  $L_{75\%}$  and Selection Factor (SF) coefficient of each escape vent (Table 2). At each escape vent size, the mean of CW of BSC was found from those data of interval class of CW then plotted on BSC number retained in the crab pot. The result of plot showed a sigmoid curve which explains a gear selection ogive of crab pot according to its escape vent size (Fig. 6-8).

## DISCUSSION

The idea of conducting this study using the escape vent attached in left and right sides of the crab pots was based on anxiety of me regarding very intensive BSC exploitation in the entire coastal areas of Indonesia, particularly in Southeast Sulawesi waters, the second BSC production in Indonesia after the northern coastal of Java. It had been initiated forming "the BSC Data Management Committee" but did not solve the main problems of BSC over exploitation. The very fast effort to overcome those problems is restraining or managing the BSC

Table 1: Estimation of gear selection ogive of crab pot for each escape vent size and attached codend

| CW interval L1-L2 | No. retained in the crab pot (ind) | No. escaped (in the codend) (ind) | Total (ind) | Proportion retained $S_L$ observation | $\ln (1/S_L - 1)$ (y) | Mean CW $(L1+L2)/2$ (x) | Proportion retained $S_L$ est |
|-------------------|------------------------------------|-----------------------------------|-------------|---------------------------------------|-----------------------|-------------------------|-------------------------------|
| A                 | B                                  | C                                 | D           | E                                     | F                     | G                       | H                             |
| ...               | ...                                | ...                               | ...         | ...                                   | ...                   | ...                     | ...                           |
| ...               | ...                                | ...                               | ...         | ...                                   | ...                   | ...                     | ...                           |
| ...               | ...                                | ...                               | ...         | ...                                   | ...                   | ...                     | ...                           |

Intercept =  $a = S_1$ , Slope =  $-b = S_2$

$$L_{25\%} = \frac{(S_1 - \ln 3)}{S_2}$$

$$L_{50\%} = \frac{S_1}{S_2}$$

$$L_{75\%} = \frac{(S_1 + \ln 3)}{S_2}$$

$S_L$  est =  $1 / \{1 + \exp(S_1 - S_2 \times L)\}$  ( $S_L$  est used for a gear selection ogive curve) and SF =  $L_{50\%}$  / escape vent size

$S_L$  obs: No. of BSC with CW L in the crab pot / (No. of BSC with CW L in the crab pot and codend), L: Interval of means of CW,  $L_{50\%}$ : The CW of BSC where 50% of BSC retained in crab pot and SF: Selection factor

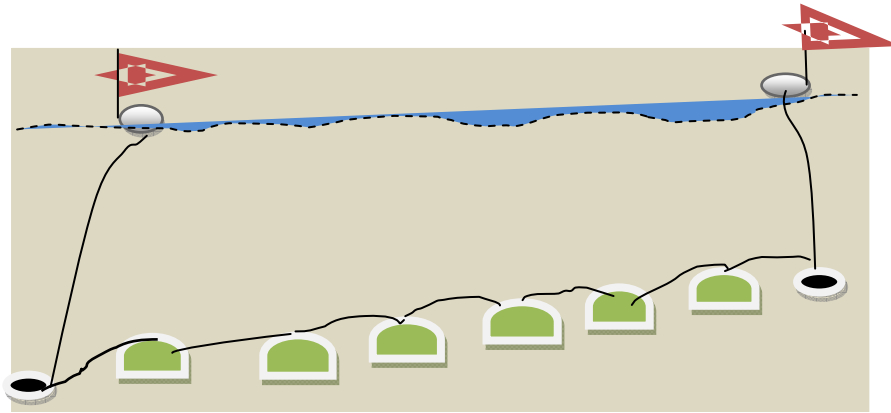


Fig. 4: Sketch of collapsible crab pots performance in the sea

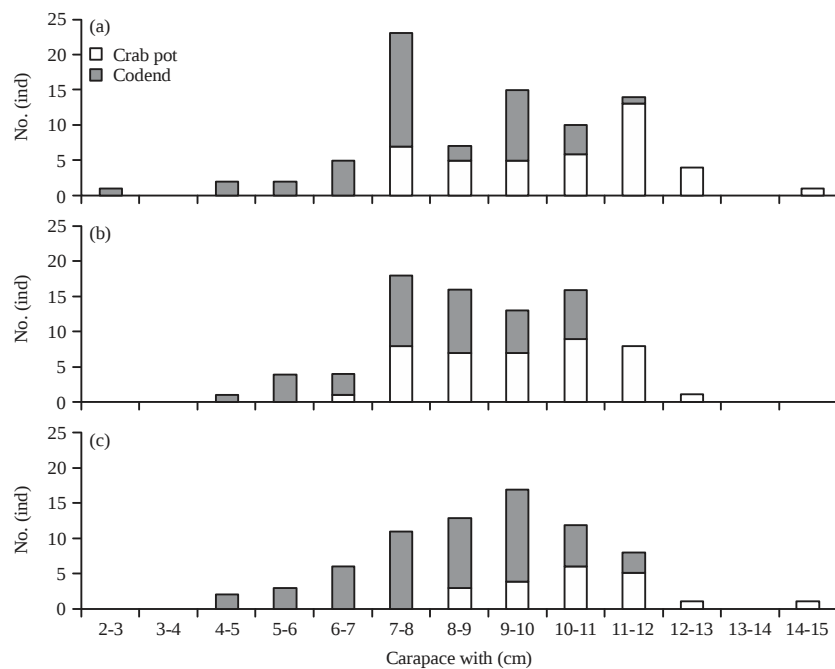


Fig. 5(a-c): Carapace width composition of BSC retained in the crab pot (dark colour) and in the codend net (white colour) according to escape vent sizes of  $4.0 \times 3.0$  cm (upper),  $4.5 \times 3.5$  cm (middle) and  $5.0 \times 3.5$  cm (below)

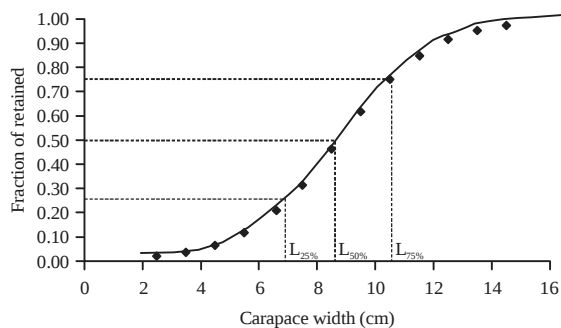


Fig. 6: A gear selection ogive of crab pot with escape vent size of  $4.0 \times 3.5$  cm ( $L_{50\%} = 8.75$  cm)

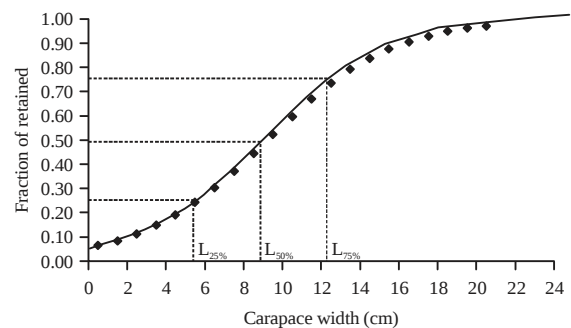


Fig. 7: A gear selection ogive of crab pot with escape vent size of  $4.5 \times 3.5$  cm ( $L_{50\%} = 9.26$  cm)

Table 2: Estimation of gear selection ogive of crab pot with escape vent size of 4.0×3.5, 4.5×3.5 and 5.0×3.5 cm

| Escape vent size (cm <sup>2</sup> ) | Intercept (a = S <sub>1</sub> ) | Slope (-b = S <sub>2</sub> ) | CW <sub>25%</sub> = (S <sub>1</sub> -ln3)/S <sub>2</sub> | CW <sub>50%</sub> = S <sub>1</sub> /S <sub>2</sub> | CW <sub>75%</sub> = (S <sub>1</sub> + ln3)/S <sub>2</sub> | SF     |
|-------------------------------------|---------------------------------|------------------------------|----------------------------------------------------------|----------------------------------------------------|-----------------------------------------------------------|--------|
| 4.0×3.5                             | 5.4854                          | 0.6272                       | 6.99                                                     | 8.75                                               | 10.50                                                     | 2.1863 |
| 4.5×3.5                             | 2.8491                          | 0.3077                       | 5.69                                                     | 9.26                                               | 12.83                                                     | 2.0575 |
| 5.0×3.5                             | 6.7910                          | 0.6323                       | 9.00                                                     | 10.74                                              | 12.48                                                     | 2.1480 |

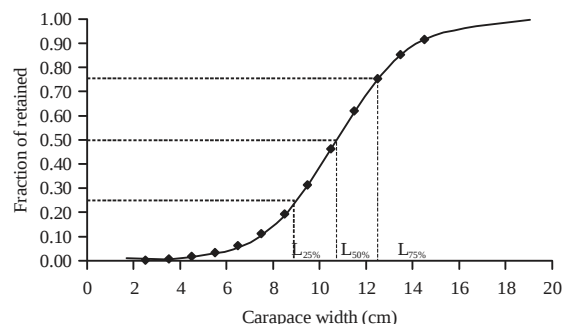


Fig. 8: A gear selection ogive of crab pot with escape vent size of 5.0×3.5 cm ( $L_{50\%} = 10.74$  cm)

sizes caught by fishermen. It is apparently in the present that BSCs caught were very apprehensive due to small sizes and low CPUE.

The BSC caught from all fishing grounds have CW interval from (2-3 cm) upto (14-15 cm) although, the number of BSC in those interval sizes were few (Fig. 5). The great number of BSC caught have CW interval from (7-8 cm) to (11-12 cm). Relatively similar data were found in Lasongko Bay of Southeast Sulawesi<sup>12</sup>, Tiworo Strait of Southeast Sulawesi<sup>10,24-26</sup> and Toronipa waters of Southeast Sulawesi<sup>27,28</sup>. Those studies showed that CW of BSCs caught with gillnets and crab pots were dominated by CW of <7.0 cm (Juvenile stage). Those data implied that BSC sizes in several coastal areas were limited to juveniles. Previous study<sup>10,24,25</sup> showed relatively similar with the present study, namely BSCs in Southeast Sulawesi waters in December, 2013 to March, 2014 (rainy season) were dominated by stage of juvenile (<6 cm) adult (>6-8 cm) while, stage of mature with CW of upto 10 cm up and stage of maturity of >11 cm were very few. Several key indicators show that BSC population is in crisis. Fishing mortality shows an increase to 4.14 while, exploitation rate is higher 0.71 than the optimal value of 0.38. The size of mature females has also decreased from 8.10-7.52 cm<sup>29</sup>.

Those BSC sizes occupied intertidal zone particularly in the waters close to mangrove areas<sup>10,24,25</sup>. In Segara Anakan lagoon *S. serrata* juveniles move forward near mangrove areas to seek for food during high tide<sup>30</sup>. This particular areas are known as a nursery ground for many species of Portunidae<sup>24,25</sup>. Due to BSC juveniles more abundance, it was set up several Marine Protected Areas (MPA) for BSC juveniles

in Tiworo Strait of Southeast Sulawesi. In line with MPA, Kunsook *et al.*<sup>29</sup> suggested a sustainable management program for BSC consisted of closing fishing ground during spawning season, restoration of seagrass beds, restocking crab larvae and educating and networking all stakeholders to develop a better of ecology of the BSC to support sustainable fishery management.

The result of present study could explain two important phenomena. First, BSCs during December, 2013 to March, 2014 in the study areas were still in the stages of juvenile-adult could be predicted that the mother of BSCs spawned and hatched their eggs since last early October, 2013 to early January, 2014 (Spawning season) due to larvae of Portunidae reach first crabs or juveniles stage after passing consecutive molting within 2 months<sup>31-36</sup>. The BSCs reach stage of adult when their CW ranging 7-8 cm and was predicted around 6-8 months old. The stage of maturity of 11 cm CW could be reached when the BSCs are 9-10 months old. Kumar *et al.*<sup>37</sup> stated that BSCs of 7-9 cm CW are around 1 year old. The female BSCs in Peel-Harvey estuary and Leschenault estuary reached the first gonad maturity when CW of 9.8 and 9.7 cm, respectively<sup>38</sup>. Those first gonad maturity of females were different with the first gonad maturity of males which were reached at CW of 8.4 and 8.8 cm, respectively. The early data are relatively similar with data of BSC caught in India waters (CW of 8.5-9.0 cm) but relatively different with females (CW of 80-90 cm)<sup>39</sup>. Therefore, the BSCs population in the study areas will achieve CW of  $\geq 10$  cm (Stage of maturity) around April-May, 2014. Second, the result of study also indicated that BSC of stage of maturity (CW of upto 11 cm) reached a peak position. If the BSCs caught allow only  $\geq 10$  cm CW that this study has given an opportunity to those BSCs maturity stage to breed (atleast once) and grow and sustain its population. The BSC individual may have 2-3 years old<sup>38</sup> means those BSCs have opportunity to breed 2-3 times due to BSCs start to breed when achieving CW of 8-9 cm.

The present data analysis of BSC caught using three escape vent sizes performed a sigmoid curve (Fig. 6-8) and curves showed that fraction of BSCs retained in the crab pots with opportunity of 50% ( $L_{50\%}$ ) to sustain BSC if the escape vent size used is 5.0×3.5 cm ( $L_{50\%} = 10.74$  cm). This recommendation is relatively similar with the recommendation implemented by fishermen and mini

plant processing in the Philippines<sup>40,41</sup>, namely >10.16 cm (120-130 g). The result of study in the Philippines showed that average of maturity size for females and males were 10.56 and 9.64 cm, respectively<sup>34,35</sup>. According to Kumar *et al.*<sup>34</sup>, females and males BSC in the Australian waters generally reached sexual maturity at the CW of 7-9 cm. Those sizes were around one year old. However, in the waters have high ecological pressure that CW at size maturity experiences changing to be smaller, for example it was found a berried female BSC of 5 months old in the Philippines waters<sup>40</sup>.

The  $L_{50\%}$  on escape vent size of  $5.0 \times 3.5$  cm is very rational to be recommended in order to sustain the BSC population and fishing effort of fishermen. The result of this escape vent size of  $5.0 \times 3.5$  cm is different with the recommendation of Boutson *et al.*<sup>42</sup>. The researchers suggested that  $4.5 \times 3.5$  cm was reduce the number of immature crabs in the catch from 70.5-11.0% while, not affecting the catch efficiency of mature size. The  $L_{25\%}$  for all escape vent sizes was not recommended due to inbenefit for fishermen although, for the sustainability of the BSC population is good. In the contrary, the  $L_{75\%}$  for all escape vent sizes also was not recommended due to around 75% of BSC retained in the crab pot have CW of stage of maturity. It means that only 25% of mature stage escape to the sea to continuously grow and breed. Therefore, the opportunity of stage of maturity in the sea to grow and breed in order to sustain its population is very low. If it happens that probably exploitation rate is higher than growth rate of BSC. This recommendation already fulfil ecological, social and economy elements particularly to sustain; (1) BSC population in the sea, (2) Opportunity for employment of fishermen, (3) Supply of BSC to the mini plant processing and benefit due to time and cost efficiency and (4) The requirement established by importers of BSC meat. Pantin *et al.*<sup>43</sup> elaborated further that the benefit using escape vents i.e., (1) Decreased potential for the selling of undersized, (2) Decreased sorting time, (3) Decreased injury or damage to undersized from handling once caught and from interactions with larger in pots, (4) Reduction in the number of undersized being eaten by other species as they descend to the bottom after discarding and (5) Reduction in the number of undersized eaten by predators because they have been discarded onto unfamiliar territory without shelter.

## CONCLUSION

In the present study, the BSCs start to spawn when their CW achieve  $\geq 10$  cm. The much appropriate escape vent size retaining the BSC CW of  $\geq 10$  cm in the collapsible crab pots is

escape vent size of  $5.0 \times 3.5$  cm as indicated by  $L_{50\%} = 10.74$  cm. This CW size has been atleast once spawning to produce offspring in order to sustain its population.

## ACKNOWLEDGMENT

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