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Selective Gap Analysis of the Escape Hatch in the Umbrella Trap with Six Doors for the Blue Swimming Crab (*Portunus pelagicus*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The blue swimming crab fishermen in Teluk Makassar, Lantebung Village tend to exploit the blue swimming crab resources without considering Sustainable Fisheries and environmental sustainability by using non-environmentally friendly fishing gear. The innovation of constructing a trap with an escape hatch is expected to provide an opportunity for undersized blue swimming crabs (carapace width < 10 cm) to escape from the trap through the escape hatch. This research aims to determine the selectivity and effectiveness of using the escape hatch to allow blue swimming crabs to escape in the waters of Teluk Makassar, Lantebung Village. The research was conducted for two months, from November to December 2022. Blue swimming crab samples were collected from foldable traps and dragon traps used by the fishermen, and the crabs were collected

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while still alive. The experimental method was employed, with four treatments and 21 replications. Based on the estimation of the selection ogive and the selectivity ogive curve, it can be concluded that the selectivity of the 3.5x4 escape hatch is more effective in allowing blue swimming crabs with carapace width below 10 cm to escape compared to other escape hatch sizes, thus avoiding the capture of immature or maturing crabs with mature gonads.

Keywords: Selectivity; escape hatch; blue swimming crab; Teluk Makassar.

1. INTRODUCTION

The blue swimming crab (*Portunus pelagicus*) is one of the economically valuable fisheries commodities, with a relatively high price of approximately Rp. 30,000 to 50,000 per kilogram of meat. Besides its high price, blue swimming crab meat is known for its delicious taste and high nutritional content [1]. The demand for blue swimming crab continues to rise, especially to meet the needs of both the local and export markets. In Indonesia, blue swimming crab is one of the fisheries commodities exported to various countries, including the United States, accounting for around 60% of the total catch. In 2015, the export volume of blue swimming crab reached 29,038 tons. Currently, the supply of blue swimming crab still heavily relies on catches from the wild [2].

Coastal communities, especially blue swimming crab fishermen, tend to exploit the crab resources without considering the principles of Sustainable Fisheries and environmental sustainability. They use non-environmentally friendly fishing gear. According to a source [3], the use of non-environmentally friendly fishing gear contributes to overexploitation of fisheries resources, including blue swimming crab, without considering the size of immature crabs that are not suitable for capture. One of the criteria for environmentally friendly fishing technology is the use of fishing gear that is selective for the target species, both in terms of species and size [4].

Modification of the trap's construction with an escape hatch is expected to provide an opportunity for small-sized blue swimming crabs (carapace width < 10 cm), which are not the primary target of the catch, to escape from the trap. Blue swimming crabs with carapace width less than 70 mm fall under the category of immature crabs (juveniles). According to a source [5], an ideal trap design will improve the effectiveness of catching blue swimming crabs while maintaining environmental sustainability.

The utilization of blue swimming crab resources should not only be focused on high catch volumes but also consider the sustainability of those resources. This means avoiding the capture and harvesting of immature blue swimming crabs, in accordance with the regulations stated in [6] Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Regulation No. 1/PERMEN-KP/2015. Article 3 of this regulation specifies the minimum size of lobster, mud crab, and blue swimming crab allowed for capture, which are carapace length > 8 cm for lobsters, carapace width > 15 cm for mud crabs, and carapace width > 10 cm for blue swimming crabs.

In recent years, there have been numerous studies conducted on the modification of blue swimming crab traps. These modifications include changes in shape, increasing the number of funnels, and adding escape hatches for the crabs [7-9]. For example, in [10], a modification was made to a rectangular foldable trap with 2 doors and equipped with a 4x3 cm escape hatch. However, the results were not selective enough and did not achieve the maximum catch of blue swimming crabs. According to a source [5], modified fishing gears with added entrances have advantages, such as having multiple entrances (multi-door), which increases the chances for blue swimming crabs to enter the trap.

In another study [11], a modification was made to the regular foldable trap with 2 doors, transforming it into a dome-shaped trap with 6 doors. This trap has 6 sides, providing a greater opportunity for blue swimming crabs to enter and be captured. Although various research on modified blue swimming crab traps aims to increase catch volumes, in this particular modification, crabs of all sizes are caught.

Considering the issue of non-selective trapping of blue swimming crabs with existing traps, it is necessary to conduct research on the addition of escape hatches to the 6-door trap. The objective of this research is to develop a selective and effective trap for capturing blue swimming crabs (*Portunus pelagicus*). The study aims to test the selectivity of using escape hatches in the 6-door trap in allowing blue swimming crabs (*Portunus pelagicus*) to escape.

2. MATERIALS AND METHODS

2.1 Location and Site

The research was conducted in the waters of Teluk Makassar, Lantebung Village, Tamalanrea Subdistrict, Makassar City (Fig. 1). The study took place over a period of two months, starting from November to December 2022. The samples of blue swimming crabs were obtained from foldable traps and crab pots, and the crabs were collected while still alive.

2.2 Materials and Equipment

The experimental materials used in this study were the blue swimmer crabs (*Portunus pelagicus*) as test subjects for the six-door escape gap. The crabs were obtained from local fishermen while still alive and temporarily held in a floating net cage to prevent mortality prior to the research. Galvanized iron wire with a diameter of 2 mm was used as the frame for the eight escape gaps. The equipment used in the study consisted of four six-door crab traps, each equipped with an escape gap (PxT) measuring 4x3 cm, 4x3.5 cm, 5x3 cm, and 5x3.5 cm respectively. A mini floating net cage was used as a container to collect the crabs that escaped through the gaps. Other equipment included a vernier caliper, a digital scale (0.01 mg), a camera, and writing materials.

2.3 Research Methodology

The research method employed in this study was experimental method, similar to previous studies [12] and [13] on crab escape gap trials. A six-door crab trap was used, which was modified to include an escape gap for the blue swimmer crabs. The escape gap had a rectangular shape, and four different sizes were tested: 4x3 cm, 4x3.5 cm, 5x4 cm, and 5x4.5 cm, as shown in (Fig. 2). The experimental trials were conducted in a floating net cage divided into four sections, each measuring 1 m x 1 m x 1 m, as depicted in (Fig. 3). Each crab trap was baited with six blue swimmer crabs of varying sizes, allowing for the observation of the size distribution of crabs escaping through the gaps. The total number of horseshoe crabs used is 502 individuals.

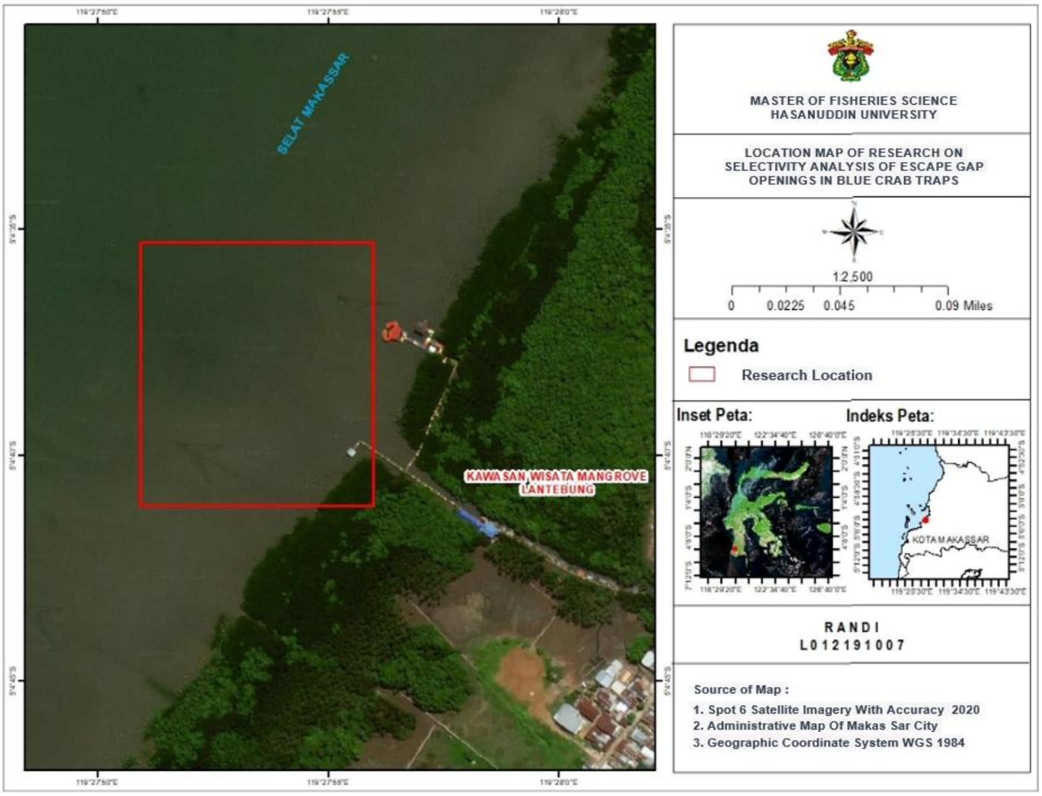

Fig. 1. Research location map

Two units of the modified six-door crab trap with escape gaps were placed in the Mini Floating Net Cage for testing the effectiveness of the crab escape gaps. The use of the floating net cage allowed for the assessment of the percentage of crabs escaping through the gaps and being retained within the cage. The number, length, and height of the carapace of crabs that escaped or did not escape through each escape gap were recorded.

2.4 Data Analysis

The variable observed in this study is the selectivity level of the escape gap. The statistical analysis of selectivity refers to the analytical model [14] in [15] and [7].

The mathematical expression to explain the selectivity of the gear is through the "logistic curve".

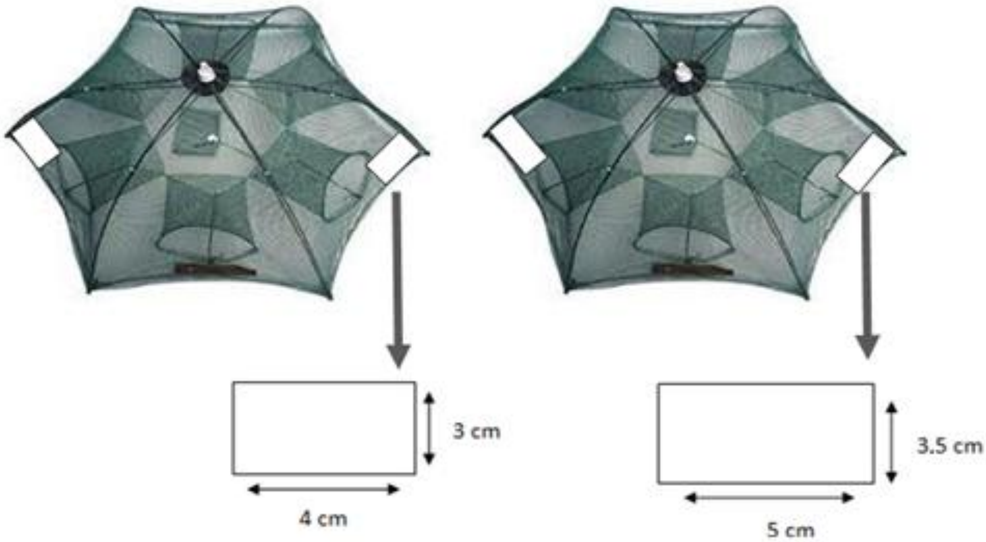

Fig. 2. Construction of 3x4 and 3.5x5 escape gaps

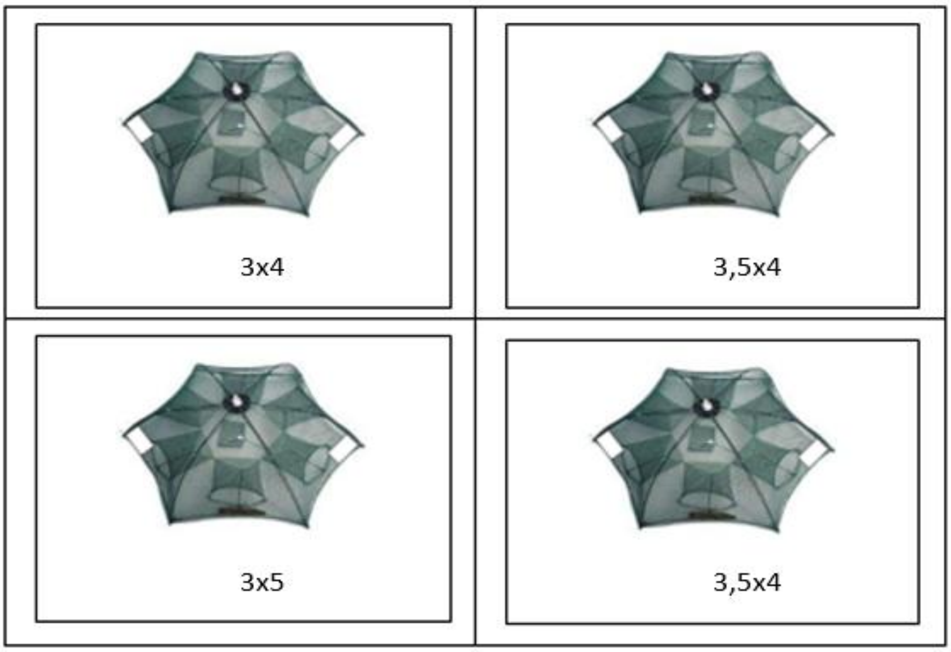

Fig. 3. Placement of traps in the floating net cage (traps 3x4, 3.5x4, 3.5x5, and 3.5x5)

Table 1. Selection estimation from the gear experiment

A	B	C	D	E	F	G	H
Length Interval L1-L2	Number in the compartment	Number escaped	Total number	Retained Portion Observed SL	ln (l/SL-1) (y)	Midpoint (L1+L2)/2 (x)	Estimated Retained portion SL

Formula: SL = (1) / (1 + exp(S1 - S2 x L))

Where

SL = proportion of crabs escaping through the escape gap / total number of crabs escaping
S1 and S2 = constants related to the gear selectivity
L = length of the crabs

Calculating the Selection Range. By applying some algebraic manipulations, it can be seen that there is a one-to-one relationship between S1 and S2 and L25, L50, and L75, which are the lengths corresponding to 25%, 50%, and 75% of the total captured crabs in a specific compartment. The length range from 25% to 75% with a symmetric shape around L50 is called the selection range. The formulas to calculate L25, L50, and L75 are:

$$L25 = \frac{S1 - \ln 3}{S2}$$

$$L50 = \frac{S1}{S2}$$

$$L75 = \frac{S1 + \ln 3}{S2}$$

The probability of a crab escaping through the escape gap depends on its body shape, particularly the height in comparison to the size of the escape gap. Therefore, it is assumed that there is a proportionality between d50 (the body height where 50% of the crabs can pass) and the size of the escape gap. The relationship is given as follows: L50 = SF * (Size of the escape gap).

To estimate the selection data from the gear experiment, it can be done using Table 1.

3. RESULTS AND DISCUSSION

Sustainable fisheries management encourages the use of environmentally friendly fishing gears. In this study, the modification of adding escape gaps to the six-door crab trap aimed to provide an opportunity for under-sized blue swimmer crabs (carapace width < 10 cm), which are not the primary target, to escape from the trap. Selectivity testing was conducted to determine the effectiveness of the escape gaps in the six-door crab trap for capturing blue swimmer crabs (*Portunus pelagicus*).

3.1 Selectivity of the 3x4 Escape Gap

Based on the research, data on the selectivity of the 3x4 escape gap for blue swimmer crabs (*Portunus pelagicus*) were obtained. The data are presented in Table 2.

Based on the estimation of the ogive selection from Table 2, it was found that the carapace width of blue swimmer crabs that can escape through the 3x4 escape gap is below the interval width of 9.5 cm. From the results of the ogive selection curve in Fig. 4, the L50% value is determined to be 9.2 cm. This suggests that blue swimmer crabs with a carapace width below 9.2 cm are likely to escape through the gap, while those with a width above 9.2 cm are likely to be captured.

3.2 Selectivity of the 3.5x4 Escape Gap

Based on the research, data on the selectivity of the 3.5x4 escape gap for blue swimmer crabs (*Portunus pelagicus*) were obtained. The data are presented in Table 3.

Table 2. Ogive selection estimation of the 3x4 escape gap for blue swimmer crabs (*Portunus pelagicus*)

Length Interval	Number Not Escaped	Number escaped	Total number	Retained Portion Observed SL	ln (I/SL-1) (y)	Midpoint (L1+L2)/2 (x)	Estimated retained portion SL
7,5-8	0	9	9	0	0	7,75	0
8-8,5	0	7	7	0	0	8,25	0
8,5-9	1	19	20	0,05	2,94	8,75	0,1
9-9,5	16	9	25	0,64	-0,58	9,25	0,6
9,5-10	32	0	32	1	0	9,75	1,0
10-10,5	10	0	10	1	0	10,25	1,0
10,5-11	14	0	14	1	0	10,75	1,0
11-11,5	4	0	4	1	0	11,25	1,0
11,5-12	4	0	4	1	0	11,75	1,0
12-12,5	1	0	1	1	0	12,25	1,0

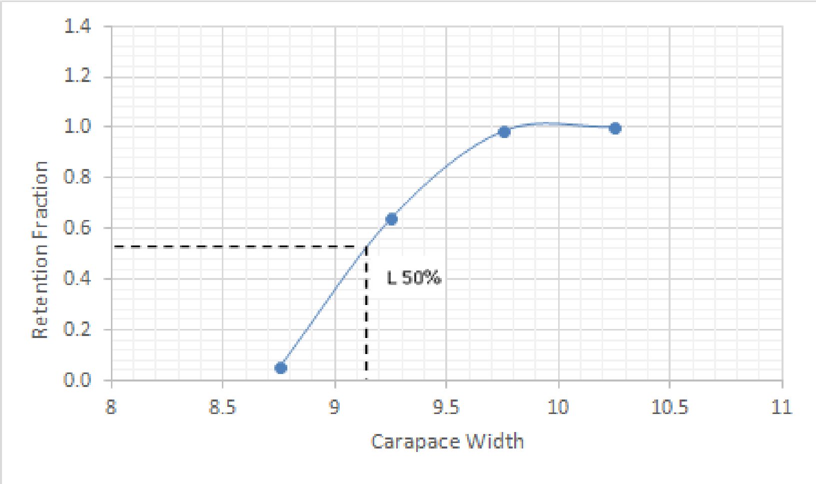

Fig. 4. Ogive selection curve of the 3x4 escape gap for blue swimmer crabs (*Portunus pelagicus*)

Based on the estimation of the ogive selection from Table 3, it was found that the carapace width of blue swimmer crabs that can escape through the 3.5x4 escape gap is below the interval width of 9.5 cm. From the results of the ogive selection curve in Fig. 5, the L50% value is determined to be 9.1 cm. This suggests that blue swimmer crabs with a carapace width below 9.1 cm are likely to escape through the gap, while those with a width above 9.1 cm are likely to be captured.

3.3 Selectivity of the 3x5 Escape Gap

Based on the research, data on the selectivity of the 3x5 escape gap for blue swimmer crabs (*Portunus pelagicus*) were obtained. The data are presented in Table 4.

Based on the estimation of the ogive selection from Table 4, it was found that the carapace width of blue swimmer crabs that can escape through the 3x5 escape gap is below the interval width of 10 cm. From the results of the ogive selection curve in Fig. 6, the L50% value is determined to be 10.2 cm. This suggests that blue swimmer crabs with a carapace width below 10.2 cm are likely to escape through the gap, while those with a width above 10.2 cm are likely to be captured.

3.4 Selectivity of the 3.5x5 Escape Gap

Based on the research, data on the selectivity of the 3.5x5 escape gap for blue swimmer crabs (*Portunus pelagicus*) were obtained. The data are presented in Table 5.

Table 3. Ogive selection estimation of the 3.5x4 escape gap for blue swimmer crabs (*Portunus pelagicus*)

Length Interval	Number Not Escaped	Number escaped	Total number	Retained portion Observed SL	ln (l/SL-1) (y)	Midpoint (L1+L2)/2 (x)	Estimated retained portion SL
7,5-8	0	16	16	0	0	7,75	0,00
8-8,5	0	8	8	0	0	8,25	1,00
8,5-9	1	8	9	0,11	2,08	8,75	0,11
9-9,5	18	9	27	0,67	-0,69	9,25	0,68
9,5-10	37	1	38	0,97	-3,61	9,75	0,97
10-10,5	6	0	6	1	0	10,25	1,00
10,5-11	12	0	12	1	0	10,75	1,00
11-11,5	6	0	6	1	0	11,25	1,00
11,5-12	3	0	3	1	0	11,75	1,00
12-12,5	0	0	0	0	0	12,25	1,00
12,5-13	1	0	1	1	0	12,75	1,00

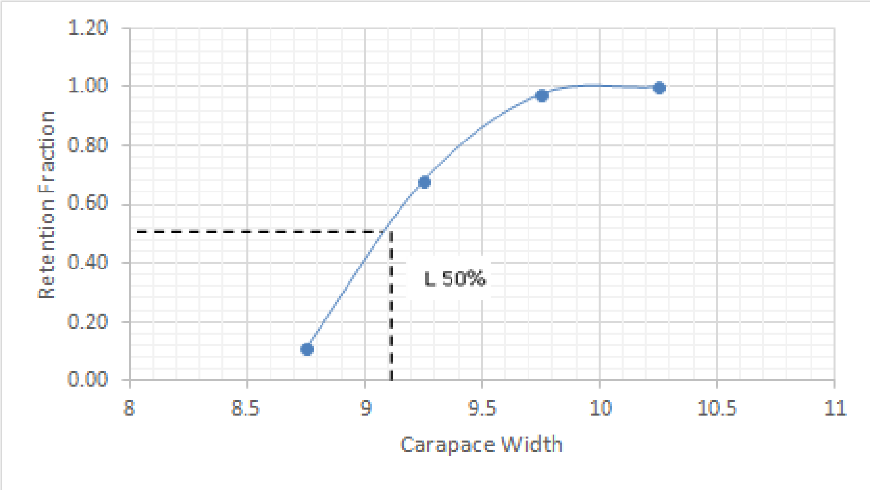

Fig. 5. Ogive selection curve of the 3.5x4 escape gap for blue swimmer crabs (*Portunus pelagicus*)

Table 4. Ogive selection estimation of the 3x5 escape gap for blue swimmer crabs (*Portunus pelagicus*)

Length Interval	Number Not Escaped	Number escaped	Total number	Retained portion Observed SL	ln (l/SL-1) (y)	Midpoint (L1+L2)/2 (x)	Estimated retained portion SL
7,5-8	1	12	13	0,08	2,48	7,75	0,09
8-8,5	1	4	5	0,20	1,39	8,25	0,13
8,5-9	3	11	14	0,21	1,30	8,75	0,20
9-9,5	5	15	20	0,25	1,10	9,25	0,28
9,5-10	4	30	34	0,12	2,01	9,75	0,39
10-10,5	7	0	7	1	0	10,25	0,50
10,5-11	24	0	24	1	0	10,75	0,62
11-11,5	8	0	8	1	0	11,25	0,72
11,5-12	1	0	1	1	0	11,75	0,81

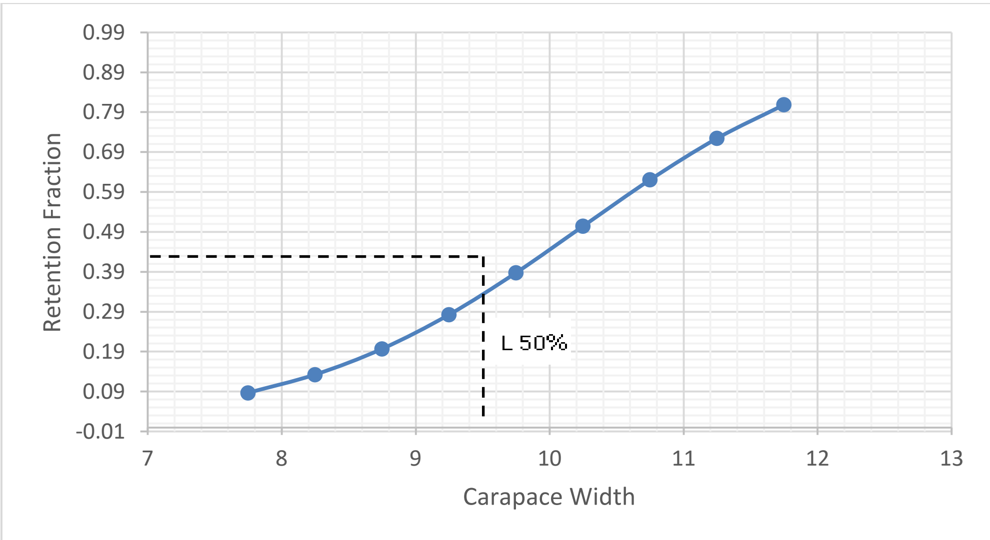

Fig. 6. Ogive selection curve of the 3x5 escape gap for blue swimmer crabs (*Portunus pelagicus*)

Table 5. Ogive selection estimation of the 3.5x5 escape gap for blue swimmer crabs (*Portunus pelagicus*)

Length Interval	Number Not Escaped	Number escaped	Total number	Retained portion Observed SL	ln (l/SL-1) (y)	Midpoint (L1+L2)/2 (x)	Estimated retained portion SL
7,5-8	0	9	9	0	0	7,75	0,08
8-8,5	1	7	8	0,13	1,95	8,25	0,10
8,5-9	1	8	9	0,11	2,08	8,75	0,12
9-9,5	2	24	26	0,08	2,48	9,25	0,14
9,5-10	10	30	40	0,25	1,10	9,75	0,17
10-10,5	0	0	0	0	0	10,25	0,20
10,5-11	15	0	15	1	0	10,75	0,24
11-11,5	12	0	12	1	0	11,25	0,28
11,5-12	3	0	3	1	0	11,75	0,33
12-12,5	2	0	2	1	0	12,25	0,37
12,5-13	2	0	2	1	0	12,75	0,43

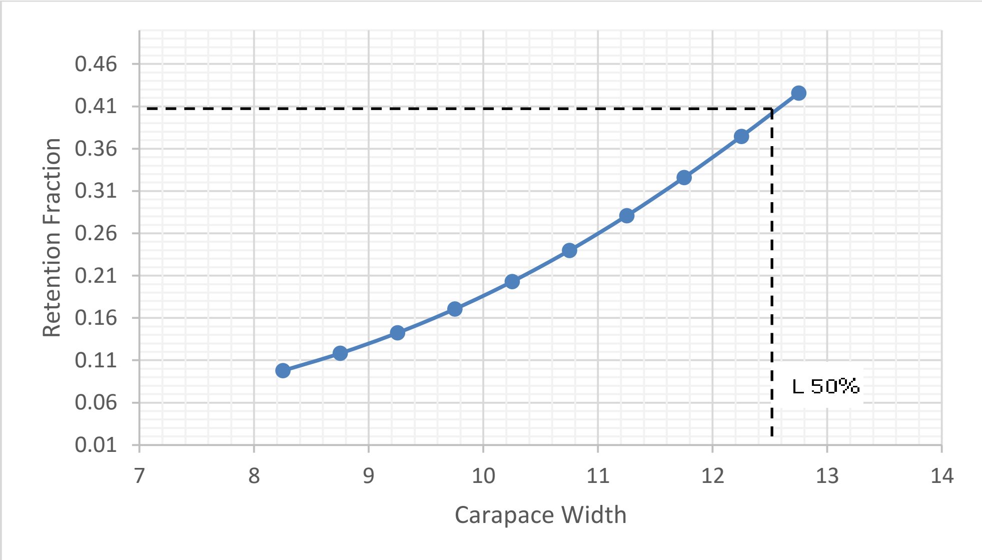

Fig. 7. Graph represents the ogive selectivity curve for the 3.5x5 escape gap for blue swimmer crabs (*Portunus pelagicus*)

Based on the estimation of the ogive selection for the 3.5x5 escape gap presented in Table 5, it was found that the width of the carapace of blue swimmer crabs (*Portunus pelagicus*) that can escape through the escape gap is below 10 cm. The selection curve in Fig. 7 shows that the L50% is at a width of 13.5 cm. Therefore, it can be estimated that blue swimmer crabs with carapace widths below 13.5 cm will escape, while those above 13.5 cm will be captured.

According to Sparre [14] in Hakim [15] and Boesono [7], selectivity in fishing is influenced by the design of the fishing gear and the characteristics of the net. These factors need to be considered when estimating the true size (or age) composition of the fish in the fishing area. Based on the conditions at the research location, the catch of crab fishermen is dominated by crabs with carapace widths below 10 cm. However, from the perspective of the first maturation size of the gonad, crabs with carapace widths above 8 cm can be considered suitable for capture. According to [16], research results show that the first maturation size of the gonad in crabs is 71.63 mm, with a carapace width range between 69.36-73.97 mm. Meanwhile, according to [17], female crabs first mature their gonads within the carapace width interval of 61-70 mm.

Based on the ogive selection estimation and ogive selection curve, out of the four sizes of escape gaps used, the 3.5x4 cm escape gap is the most effective. This escape gap can allow crabs with carapace widths below 10 cm to escape and avoid capturing crabs that have matured their gonads.

4. CONCLUSION

Based on the estimation of ogive selection and the ogive selectivity curves, it can be concluded that the 3.5x4 escape gap is more effective in allowing blue swimmer crabs with a carapace width of less than 10 cm to escape compared to other escape gaps. Additionally, this escape gap also helps in avoiding the capture of crabs that are either immature or have matured gonads, thus enhancing the sustainability of the crab population.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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