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# THE SELECTIVITY OF FISH TRAP ESCAPE GAP SIZE ON BOTANA FISH (*Acanthurus reversus*)

*Selektivitas Ukuran Celah Pelolosan Bubu Terhadap Ikan Botana (Acanthurus reversus)*

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## *ABSTRACT*

Fish trap is used due to its good prospect, particularly for demersal fish and reef fish in Maluku. A challenge of trap fisheries is the capture of various species of fish, along with a narrow size variation in the captured fish. To reduce the species diversity in the catch and allow the escape of young fish, an escape gap is recommended. This study aims to analyze the effect of different escape gap sizes on the fish that escape and their chances of being caught or escaping relative to the dominant catch. The study was conducted from July to September 2021 in the waters of Eri Village, Nusaniwe District, Ambon City, Indonesia. The experimental fishing method was used in the field. The results indicated that the size of the escape gap had no effect on the number of fish that escaped through each escape gap. The 50% probability of *Achanturus reversus* escaping from the size 2.0 cm escape gap is in the total length range of 21-22 cm, while from a 3.0 cm escape gap is 24-25 cm.

***Keywords:*** Fish pot, escape gap, selectivity

## ABSTRAK

Alat tangkap bubu digunakan karena prospeknya sangat baik terutama untuk ikan demersal dan ikan karang di Maluku. Permasalahan yang dihadapi oleh perikanan bubu adalah hasil tangkapan terdiri dari berbagai spesies, selain itu, ukuran ikan yang tertangkap dengan variasi yang kecil. Salah satu cara yang perlu dilakukan untuk meloloskan ikan yang belum layak ditangkap dan mengurangi keragaman jenis yang tertangkap dengan menggunakan celah pelolosan. Penelitian ini bertujuan untuk menganalisis pengaruh perbedaan ukuran celah pelolosan terhadap hasil tangkapan yang lolos dan menganalisis peluang ikan-ikan yang tertangkap dan lolos terhadap hasil tangkapan dominan. Penelitian dilakukan pada bulan Juli sampai September 2021 di Perairan Dusun Eri, Kecamatan Nusaniwe, Kabupaten Kota Ambon, Indonesia. Metode yang digunakan adalah *experimental fishing* langsung di perairan. Hasil penelitian menunjukkan bahwa ukuran celah pelolosan tidak berpengaruh terhadap jumlah ikan yang lolos pada tiap celah pelolosan. Peluang untuk lolos 50% ukuran ikan *Achanturus reversus* dari celah pelolosan 2,0 cm pada kisaran panjang total 21-22 cm, sedangkan dari celah pelolosan 3,0 cm adalah 24-25 cm.

**Kata kunci:** bubu, celah pelolosan, selektivitas.

## INTRODUCTION

One fishing gear that is commonly used today is the pot. This fishing gear is preferred due to its effectiveness, especially for catching demersal fish and coral fish. Compared to other fishing gear, fish pot is quite selective in catching these types of fish. Using fish pot is also in line with the Code of Conduct for Responsible Fishing, which emphasizes the use of selective fishing gear and minimizing non-target catches (Afoakwah *et al.* 2018). In

Indonesia, fishers use several types of pots, including folding pots, cages, cylindrical pots, drums, semi-circular tambon pots, and others (Martasuganda 2008). In Maluku, drum pots and tambon pots are commonly used, both designed with a horse neck funnel.

Fishermen in Maluku use pots called Buton pots to catch fish. These pots are shaped like arrowheads and are made from woven bamboo. The bamboo has small hexagonal gaps. The pots are installed in coral waters at low tide, at a depth of 3-5 meters. They catch several types of fish, some with important economic value such as *Parupeneus sp, Epinephelus sp, and Lethrinnus sp*. Other catches include various species like Chaetodonidae, Balistapusidae, Scorpaenodidae, and others that are not belong to important economic value.

The problem faced by pot fisheries is that their catch includes various species of fishes, along with a wide range of sizes. Research conducted by Fachrussyah & Zaman (2020) showed that during 20 trips by 20 individuals, a total of 109 fish were caught, consisting of 11 different species, including small fishes that were not yet mature. To prevent catching immature fish and to reduce the diversity of species caught, an escape gap can be used. Escape gaps have been utilized by various researchers to avoid catching fish that are not yet mature or have not yet reached the length at first maturity (Johnson 2010; Mbaru & McClanahan 2013; Broadhurst 2017; Adyatma 2020; Tuhumury *et al*. 2022). The focus of this research is on Acanthurus reversus fish. This species is important in the coral ecosystem and has significant economic value. However, Acanthurus reversus is often caught in traps before reaching its mature size. We need to find a solution to ensure that only mature fish are caught. This aligns with efforts to maintain the sustainability of the fish population and fisheries in the Maluku region.

Research has shown that using escape gaps can help decrease the number of unwanted species and small fish caught. However, using a box-shaped escape gap can still lead to some issues, such as the likelihood of certain types of fish getting caught, and many fish being injured while trying to escape from bamboo pots (Hehanussa *et al*. 2017). Additionally, increasing the size of the escape gap is necessary to reduce the number of unwanted species and sizes caught (Rahman *et al*. 2021). One possible solution is to construct the pot using an iron frame and PE netting, with a four squares iron bar escape gap along the length of the pot at the bottom. If the fish escapes through the bars, it will be caught in the cover. This research aims to analyze the effect of the escape gap on the catch of fish that escape and analyze the selectivity of pots on the catch of *Acanthurus reversus* fish.

## METHOD

The study was carried out between July and September 2021 in the waters of Eri Hamlet, Nusaniwe District, Ambon City Regency. The experimental fishing method was used in this research by conducting fishing trials directly in the waters. The study used three pots as experimental units, while the treatment was the size of escape gap made of iron bars. The distance between the bars were 2.0 cm, 2.5 cm, and 3.0 cm, respectively.

The bars were installed along the bottom of the pot (90 cm), and the bottom of the grate served as a cover to accommodate the catch of fish that escaped. The data collected during the study included the type and length of the fish. The tools and materials used in this research included three units of pots made of iron frames and equipped with escape gaps made of iron bars measuring 2.0 x 90 cm, 2.5 x 90 cm, and 3.0 x 90 cm. To operate the pot, a lookout glass made of 3 mm board in the shape of a cube measuring 50 cm high and 25 cm wide was used and GPS was used to determine the position of the research site. A ruler with an accuracy of 0.1 cm was used to measure the total length of the fish.

### Pot design and net cover construction

The pot is inspired by the shape of pots that are commonly used by fishermen in Maluku, known as the button or tambon pot. The pot takes the form of a funnel with a shape resembling a horse's neck. The bubu frame is constructed from standard 8 mm concrete steel that is cut to size and then assembled with welded joints to form the tambon pot, as shown in Figure 1. The pot measures 90 cm in length and 60 cm in width, with an overall height of 70 cm. However, the height of the pot is divided into two parts: the cover is 20 cm high, limited by the escape gap, and the pot itself is 50 cm high.

The pot's funnel mouth is shaped like a horse's neck and has two parts: the outer funnel mouth and the inner funnel, measuring 24 cm and 14 cm respectively. The mouth of the funnel is circular in shape. Figure 1 shows a visual representation of the pots design and dimensions.

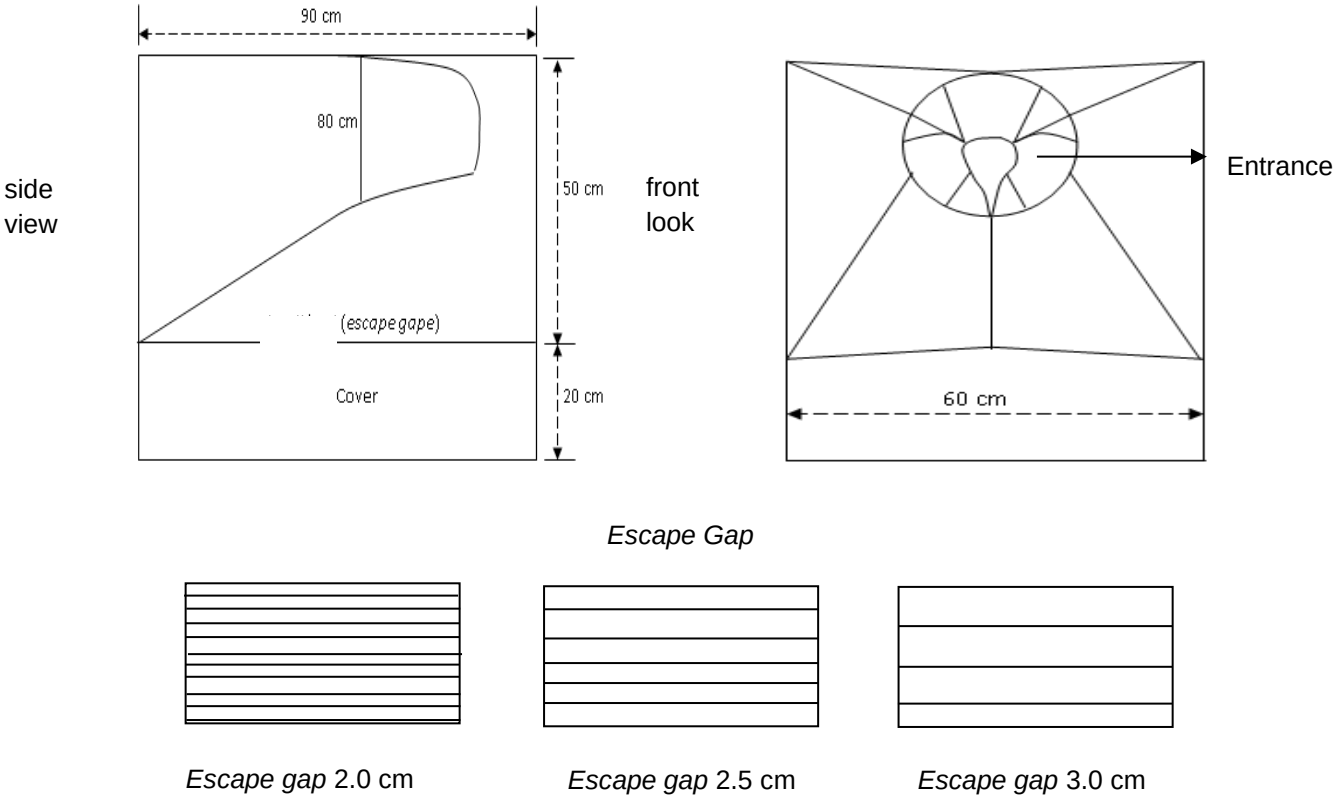


Figure 1 Design and dimensions of pot frame

An additional pocket called a cover net is installed in the escape gap. This cover net is made of PE net with an eye size of 1 inch and is only installed at the bottom of the pot. The purpose of the cover net is to allow small fish to escape through the escape gap and be caught in the net cover (or wrapping net) when the pot is lifted (hauling). The use of cover nets in pot makes easier for researchers to compare the type, number, and size of fish that escape through the escape gap. This technique has been studied by various researchers in the past, including Sparre & Venema 1999, Madsen *et al*. 2001, Frandsen *et al*. in 2010, Yusrizal 2011, Sudirman *et al*. 2014, Tallo 2015, and Hehanussa *et al*. 2017. The pot fishing gear uses square escape gaps measuring 2 cm, 2.5 cm, and 3 cm based on the flat bodies of reef fish. The square shape allows fish with different body orientations to escape more effectively. A 2 cm gap lets juveniles escape, a 2.5 cm gap helps slightly larger fish to escape, and a 3 cm gap ensures that only adults are caught. Using these square gaps reduces stress and the risk of injury to fish, increases catch selectivity, reduces bycatch, and supports fisheries regulations aimed at the sustainability and protection of coral

**Data analysis**

Data regarding the length of the most frequently caught fish species for each treatment has been presented in a graphical

format. The difference in the number of fish caught between treatments, that passed through the escape gap, has been analyzed using the non-parametric statistical tool called the Firmman's Test (Steel and Torie 1993). This test follows a specific formula.

$$\mathcal{X}_r^2 = \left[\frac{12}{(nxk)(k+1)}\sum_{j=1}^{k}\left(R_j\right)^2\right] - [(3n)(k+1)] \text{..(1)}$$

With :
$\mathcal{X}_r^2$ = Friedman two-way level chi-square value
n = Group
k = Treatment
1,3,12 = Constant
$R_j$ = Number of rankings
Db = k - 1

To determine the probability of fish passing through or getting potped in the escape gap, the logistic function model is used (Sparre and Venema 1999). It shows the probability of each class of total length of fish for the dominant type of fish caught.

$$SL = \frac{Exp\ (a+bx)}{1+Exp(a+bx)} \text{ ..... (2)}$$

with :
SL = probability of passing the fish total length (L) size class
a = intersection point of the line equation
b = line coefficient
x = number of long classes

## RESULTS

### Composition and number of catches in pots and cover nets

Fish caught during the study were 242 individuals, composed of 25 types of fish and 1 (one) type of crustacean (Table 1). The catch is dominated by gotana fish (*Acanthurus reversus*), followed by kepe-kepe (*Chaetodon klenii*) and Kulit pasir (*Naso vlamingii*).

Table 1 Composition of catches (individuals) in pots and cover nets

| No. | Types of Fish | Catch | |
|---|---|---|---|
| | | Individual | % |
| 1 | Gotana1 (*Acanthurus reversus*) | 57 | 23 |
| 2 | Gotana2 (*Acanthurus pyroferus*) | 9 | 3.7 |
| 3 | Gotana3 (*Acanthurus nigricauda*) | 8 | 3.3 |
| 4 | Gotana4 (*Acanthurus xanthopterus*) | 5 | 2.1 |
| 5 | Kepe-kepe1 (*Chaetodon kleini*) | 47 | 19.9 |
| 6 | Kepe-kepe2 (*Chaetodon selene*) | 13 | 5.4 |
| 7 | Kepe-kepe3 (*Chaetodon baronessa*) | 7 | 2.9 |
| 8 | Kuli Pasir1 (*Naso vlamingii*) | 30 | 12.4 |
| 9 | Kuli pasir2 (*Naso lituratus*) | 11 | 4.6 |
| 10 | Kerapu tikus (*Cromileptes altiveles*) | 7 | 2.9 |
| 11 | Garopa (*Epinephelus fuscoguttatus*) | 2 | 0.8 |
| 12 | Kakap merah (*Lutjanus campecanus*) | 1 | 0.4 |
| 13 | Kakap hitam (*Micropterus dolemicu*) | 1 | 0.4 |
| 14 | Kakatua (*Scerus niger*) | 3 | 1.2 |
| 15 | Poro bibi (*Famela* Sp) | 3 | 1.2 |
| 16 | Peti (*Ostraction cubicus*) | 1 | 0.4 |
| 17 | Lalosi (*Chaesio cuning*) | 6 | 2.5 |
| 18 | Sikuda (*Lates calcarifer)* | 1 | 0.4 |
| 19 | Samandar (*Siganus caralitulatus*) | 14 | 5.8 |
| 20 | Tatu1 (*Cantherhines fronticintus*) | 4 | 1.7 |
| 21 | Tatu2 (*Aluterus scripstus*) | 3 | 0.4 |
| 22 | Tatu3 (*Balistes viridescense*) | 3 | 0.4 |
| 23 | Trompet (*Aulostomus chinensis*) | 1 | 0.4 |
| 24 | Belut (*Gimnopthorax moringa*) | 3 | 1.2 |
| 25 | Udang Barong (*Panulirus* Sp) | 1 | 0.4 |
| | **Amount** | **242** | **100** |

Table 2 Percentage of catch composition (individuals) that passed through the escape gap.

| No | Types of Fish | Gap 2.0 cm | | | Gap 2.5 c m | | | Gap 3.0 cm | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ***Catch*** **(Individual)** | **Get away (Individual)** | % | ***Catch*** **(Individual)** | **Get away (Individual)** | % | ***Catch*** **(Individual)** | **Get away (Individual)** | % |
| 1 | *Acanthurus reversus* | 26 | 15 | 57.7 | 12 | 8 | 66.7 | 19 | 9 | 47.4 |
| 2 | *Acanthurus pyriferus* | 3 | - | 0.0 | 2 | 2 | 100.0 | 4 | 2 | 50.0 |
| 3 | *Acanthurus nigricauda* | 2 | 2 | 100.0 | 1 | - | 0.0 | 5 | 3 | 60.0 |
| 4 | *Acanthurus xantopterus* | 1 | | 0.0 | 2 | | 0.0 | 2 | 1 | 50.0 |
| 5 | *Chaetodon Kleini* | 20 | 20 | 100.0 | 17 | 17 | 100.0 | 11 | 11 | 100.0 |
| 6 | *Chaetodon selene* | 6 | 6 | 100.0 | 4 | 4 | 100.0 | 3 | 3 | 100.0 |
| 7 | *Chaetodon baronessa* | 3 | 3 | 100.0 | 1 | 1 | 100.0 | 3 | 3 | 100.0 |
| 8 | *Naso vlamingi* | 10 | - | 0.0 | 8 | 2 | 25.0 | 12 | - | 0.0 |
| 9 | *Naso lituratus* | 7 | - | 0.0 | - | - | - | 4 | - | 0.0 |
| 10 | *Cromileptes altifeles* | 3 | - | 0.0 | 3 | - | 0.0 | 1 | - | 0.0 |
| 11 | *Epinephelus fuscoguttatus* | 2 | - | 0.0 | - | - | - | - | - | - |
| 12 | *Lutjanus campechanus* | - | - | - | 1 | - | 0.0 | - | - | - |
| 13 | *Micropterus salmoides* | 1 | - | 0.0 | - | - | - | - | - | - |
| 14 | *Scarus niger* | 2 | - | 0.0 | - | - | - | 1 | 1 | 100.0 |
| 15 | *Otraction cubicus* | 1 | - | 0.0 | - | - | - | - | - | - |
| 16 | *Famells* SP | 3 | - | 0.0 | - | - | - | - | - | - |
| 17 | *Chaesio cuning* | 1 | - | 0.0 | 2 | - | 0.0 | 3 | - | 0.0 |
| 18 | *Lates calcarifer* | - | - | - | - | - | | 1 | - | 0.0 |
| 19 | *Siganus caralitulatus* | 5 | - | 0.0 | 9 | - | 0,0 | - | - | - |
| 20 | *Cantherhines fronticintus* | - | - | - | 3 | 2 | 66.7 | 1 | - | 0.0 |
| 21 | *Aluterus scriptus* | - | - | - | 1 | 1 | 100.0 | 2 | 1 | 50.0 |
| 22 | *Balistes viridescense* | - | - | - | 1 | - | 0.0 | 2 | 1 | 50.0 |
| 23 | *Aulostomus chinensis* | 1 | 1 | 100.0 | - | - | - | - | - | - |
| 24 | *Gimnopthorax moringa* | 1 | 1 | 100.0 | 2 | - | 0.0 | - | - | - |
| 25 | *Panulirus* SP | - | - | - | - | - | - | 1 | - | 0.0 |
| | **Amount** | **98** | **52** | **53.1** | **69** | **37** | **53.6** | **75** | **35** | **46.7** |

The genus *Chaetodon* consists of three types of butterflyfish, namely *Chaetodon kleinii, Chaetodon selene*, and *Chaetodon baronessa*. The sand porter fish category has two types, namely *Naso vlamingii* and *Naso lituratus*, while the gotana fish category consists of four types, namely *Acanthurus reversus*, *Acanthurus pyroferus*, *Acanthurus nigricauda*, and *Acanthurus xanthopterus*.

Table 2 indicates that 53.1% of fish caught passed through the 2.0 cm escape gap, 53.6% passed through the 2.5 cm escape gap,

and 46.7% passed through the 3.0 cm escape gap. Among the 25 types of fish caught during the research, 19 types of fish were caught in pots with a 2.0 cm escape gap, and of these 19 fish species, seven had an escape percentage of 100%. The seven fish types that escaped the pots were *Chaetodon kleinii*, *Chaetodon selene*, *Chaetodon baronessa*, *Acanthurus pyroferus*, *Acanthurus nigricauda*, *Gimnothorax moringa*, and *Aulostomus chinensis*. There are 11 types of fish that enter the pot and do not pass through the 2.0 cm escape gap, including *Naso vlamingii*, *Naso lituratus*, *Acanthurus xanthopterus*, *Cromileptes altivelis*, *Siganus caralitulatus*, *Caesio cuning*, *Epinephelus fuscogutattus*, *Micropterus dolemicu*, *Scarus niger*, and *Ostraction cubicus*. The *Acanthurus reversus* fish type had a 57.3% escape rate and a 42.7% retention rate.

During the research, pots with an escape gap of 2.5 cm were used to catch 16 types of fish. Out of those 16 types, eight types of fish were unable to pass through the escape gap, while five types passed through the gap without any issue. Three types of fish managed to pass through with a certain percentage of success. The eight types of fish that were unable to pass through the 2.5 cm gap were *Acanthurus nigricauda*, *Acanthurus xanthopterus*, *Cromileptes altivelis*, *Balistes virideskense*, *Siganus caralitulatus*, *Gimnopthorax moringa*, *Caesio cuning* and *Lutjanus campecanus*. The five types of fish that passed 100% through the 2.5 cm escape gap were *Chaetodon kleinii*, *Chaetodon selene*, *Chaetodon baronessa*, *Aloterus scriptus*, and *Acanthurus pyroferus*. Three other types of fish that had a certain percentage of passes were *Acanthurus reversus* (47.4% passed), *Cantherhines fronticinctus* (66.7%), and *Naso vlamingii* (25.0%).

In another experiment, pots with an escape gap of 3.0 cm were used to catch 17 types of fishes and 1 type of *crustacean*. Out of those 17 species of fish, seven types of fish were unable to pass through the escape gap, while four types passed through without any issue. Six types of fishes managed to pass through the gap with a certain percentage of success. The six types of fishes that were unable to pass through the 3.0 cm gap were *Naso vlamingii*, *Naso lituratus*, *Cromileptes altivelis*, *Cantherhines fronticintus*, *Late cacarifer*, and *Caesio cuning*. The four types of fishes that passed 100% through the 3.0 cm escape gap were *Chaetodon kleinii*, *Chaetodon selene*, *Chaetodon baronessa* and *Scarus niger*. The six types of fish that had a certain percentage of escapes were *Acanthurus reversus* (66.7% passed), *Acanthurus pyroferus* (50.0%), *Acanthurus nigricauda* (60.0%), *Acanthurus xanthopterus* (50.0%), *Aluterus sciptus* (50.0%) and *Balistes viridescense* (50.0%).

**Composition of catch size**

*Chaetodon*, *Naso*, and *Acanthurus* were the most common fish species caught. Table 3 displays their size distribution.

The following are the ranges of total length of three different types of fish caught and escaped through various escape gaps: For *Chaetodon kleinii* fish that escaped through the 2.0 cm escape gap, the range was 10.0 – 15.1 cm (with a standard deviation of 1.2). For *Chaetodon selene*, the total length range was 11.0 – 15.3 cm (with a standard deviation of 1.6), and for *Chaetodon baronessa*, the total length range was 12.2 – 15.3 cm (with a standard deviation of 1.6). For *Chaetodon kleinii* fish that escaped through the 2.5 cm escape gap, the range was 8.5 – 15.8 cm (with a standard deviation of 1.2). For *Chaetodon selene*, the total length range was 15.3 – 15.8 cm (with a standard deviation of 0.2), and for *Chaetodon baronessa*, the total length was 14.3 cm. For *Chaetodon kleinii* fish that passed through the 3.0 cm escape gap, the range was 9.8 – 15.2 cm (with a standard deviation of 1.2). For *Chaetodon selene*, the total length range was 11.0 – 12.8 cm (with a standard deviation of 0.9), and for *Chaetodon baronessa*, the total length range was 13.7 – 15.0 cm (with a standard deviation of 0.7.

The *Naso flaming* fish species cannot pass through escape gap sizes of 2.0 cm and 3.0 cm. The fish that did not pass through the 2.0 cm gap had a total length ranging from 21.5 cm to 26.7 cm (with a standard deviation of 2.1), and those that did not pass through the 3.0 cm gap had a total length ranging from 22.1 cm to 26.5 cm (with a standard deviation of 1.6). When a pot with a 2.5 cm escape gap was used, the total length of the caught fish ranged from 17.3 cm to 25.3 cm (with a standard deviation of 3.3), and the range of total length of fish that escaped through the gap was from 17.3 cm to 17.6 cm (with a standard deviation of 0.2). The *Naso lituratus* fish species were also caught and did not pass through the 2.0 cm and 3.0 cm escape gaps. The total length of the fish that did not pass through the 2.0 cm gap ranged from 27.0 cm to 27.9 cm (with a standard deviation of 0.4), and that did not pass through the 3.0 cm gap ranged from 27.1 cm to 29.2 cm (with a standard deviation of 0.9).

Table 3 Size composition of dominant fish caught during the experiment.

| Type of fish | Escape gap 2.0 cm | | Escape gap 2.5 cm | | Escape gap 3.0 cm | |
|---|---|---|---|---|---|---|
| | *Catch (cm)* | Get away (cm) | *Catch (cm)* | Get away (cm) | *Catch (cm)* | Get away (cm) |
| ***Chaetodon kleinii*** | | | | | | |
| Average total length | 11.2 | 11.2 | 12.7 | 12.7 | 12.5 | 12.5 |
| Minimum total length | 10.0 | 10.0 | 8.5 | 8.5 | 9.8 | 9.8 |
| Maximum total length | 15.1 | 15.1 | 15.8 | 15.8 | 15.2 | 15.2 |
| SD | 1.2 | 1.2 | 2,3 | 2.3 | 1.8 | 1.8 |
| ***Chaetodon selene*** | | | | | | |
| Average total length | 13.4 | 13.4 | 15.5 | 15.5 | 11.8 | 11.8 |
| Minimum total length | 11.0 | 11.0 | 15.3 | 15.3 | 11.0 | 11.0 |
| Maximum total length | 15.3 | 15.3 | 15.8 | 15.8 | 12.8 | 12.8 |
| SD | 1.6 | 1.6 | 0.2 | 0.2 | 0.9 | 0.9 |
| ***Chaetodon baronessa*** | | | | | | |
| Average total length | 13.8 | 13.8 | 14.3 | 14.3 | 14.4 | 14.4 |
| Minimum total length | 12.2 | 12.2 | 14.3 | 14.3 | 13.7 | 13.7 |
| Maximum total length | 15.3 | 15.3 | 14.3 | 14.3 | 15.0 | 15.0 |
| SD | 1.6 | 1.6 | - | - | 0.7 | 0.7 |
| ***Naso vlamingii*** | | | | | | |
| Average total length | 24.3 | - | 21.2 | 17.5 | 24.6 | - |
| Minimum total length | 21.5 | - | 17.3 | 17.3 | 22.1 | - |
| Maximum total length | 26.7 | - | 25.3 | 17.6 | 26.5 | - |
| SD | 2.1 | - | 3.3 | 0.2 | 1.6 | - |
| ***Naso lituratus*** | | | | | | |
| Average total length | 27.5 | - | - | - | 28.4 | - |
| Minimum total length | 27.0 | - | - | - | 27.1 | - |
| Maximum total length | 27.9 | - | - | - | 29.2 | - |
| SD | 0.4 | - | - | - | 0.9 | - |
| ***Acanthurus reversus*** | | | | | | |
| Average total length | 21.2 | 20.3 | 22.4 | 20.7 | 24.8 | 22.9 |
| Minimum total length | 17.4 | 17.4 | 17.3 | 17.3 | 19.2 | 19.2 |
| Maximum total length | 26.4 | 23.3 | 28.2 | 22.2 | 28.7 | 25.3 |
| SD | 2.3 | 1.8 | 2.9 | 1.7 | 2.5 | 2.0 |
| ***Acanthurus pyroferus*** | | | | | | |
| Average total length | 18.1 | 18.1 | 18.0 | 18.0 | 24.9 | 21.9 |
| Minimum total length | 17.2 | 17.2 | 17.3 | 17.3 | 21.3 | 21.3 |
| Maximum total length | 18.7 | 18.7 | 18.7 | 18.7 | 28.6 | 22.4 |
| SD | 0.8 | 0.8 | 1.0 | 1.0 | 3.6 | 0.8 |
| ***Acanthurus nigricauda*** | | | | | | |
| Average total length | 18.6 | 18.6 | 26.1 | - | 22.54 | 20.3 |
| Minimum total length | 17.5 | 17.5 | 26.1 | - | 19.5 | 19.5 |
| Maximum total length | 19.7 | 19.7 | 26.1 | - | 27.1 | 21.5 |
| SD | 1.6 | 1.6 | - | - | 3.4 | 1.1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Acanthurus xanthopterus*** | | | | | | |
| Average total length | 27.3 | - | 26.8 | - | 25.5 | 21.8 |
| Minimum total length | 27.3 | - | 26.4 | - | 21.8 | 21.8 |
| Maximum total length | 27.3 | - | 27.1 | - | 29.1 | 21.8 |
| SD | - | - | 0.5 | - | 5.2 | - |

The Naso flaming fish species was observed to be unable to escape from escape gap sizes of 2.0 cm and 3.0 cm. The total length of this type of fish that could not pass through the 2.0 cm escape gap ranged from 21.5 to 26.7 cm (with a standard deviation of 2.1), while that which could not pass through the 3.0 cm escape gap ranged from 22.1 cm to 26.5 cm (with a standard deviation of 1.6). The total length of fish caught with a pot measuring a 2.5 cm escape gap ranged from 17.3 cm to 25.3 cm (with a standard deviation of 3.3). The range of total length that escaped from the escape gap was between 17.3 cm and 17.6 cm (with a standard deviation of 0.2). Similarly, the *Naso lituratus* fish species was caught and was unable to pass through the 2.0 cm and 3.0 cm escape gaps. The total length that could not pass through the 2.0 cm escape gap ranged between 27.0 cm and 27.9 cm (with a standard deviation of 0.4), while that which could not pass through the 3.0 cm escape gap ranged from 27.1 cm to 29.2 cm (with a standard deviation of 0.9).

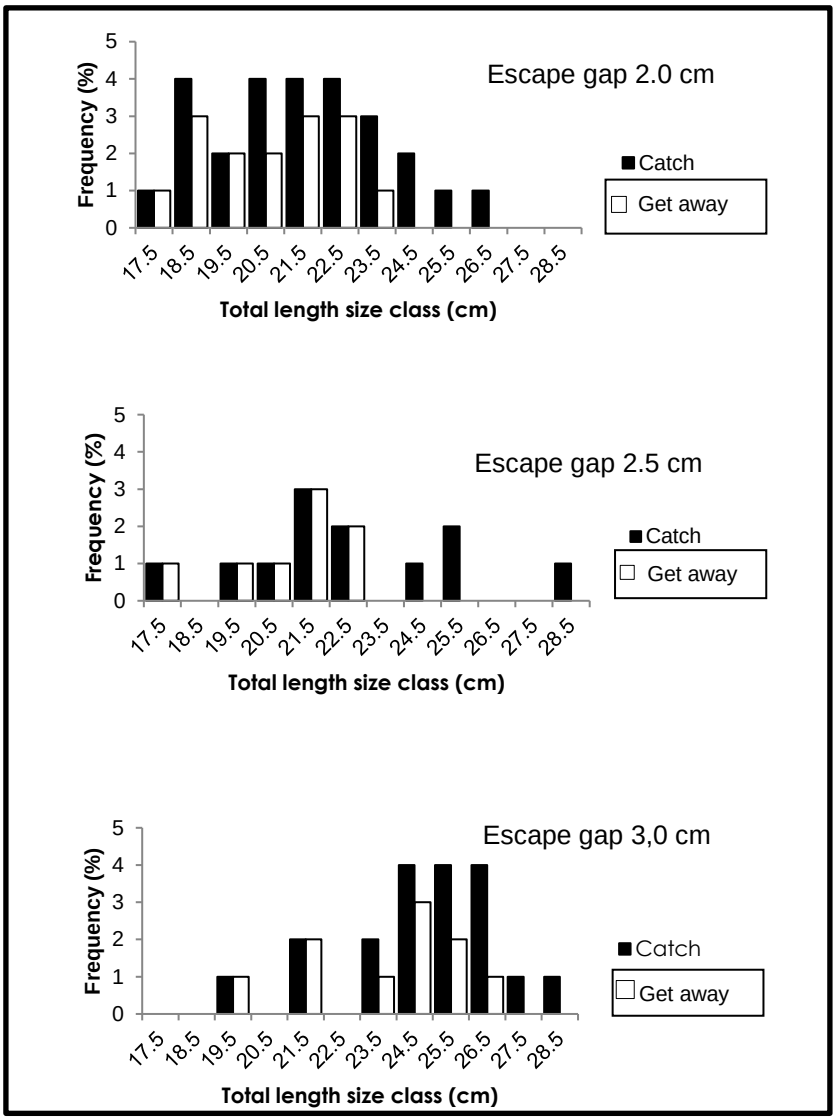


Figure 2 Frequency of catching and escaping based on total length (cm) class of *Acanthurus reversus* fish from escape gap sizes of 2.0 cm, 2.5 cm and 3.0 cm.

Bubu used a pot with an escape gap of 2.0 cm to catch *Acanthurus pyroferus*. However, all of the caught fish managed to escape through the gap. On the other hand, fish caught with a pot having an escape gap of 2.5 cm preferred a total length ranging from 17.3 cm to 18.7 cm (SD 1.0), but they also escaped through the gap. The pot with an escape gap of 3.0 cm caught *Acanthurus* prefers fish having a total length between 21.3 cm and 28.6 cm (SD 3.6), but some fish still managed to escape, with their total length ranging from 21.3 cm to 22.4 cm (SD 0.8).

The following data was collected from a study on fish potped with varying escape gap sizes: A pot with a 2.0 cm escape gap caught *Acanthurus nigricauda* fish with a total length ranging from 17.5 cm to 19.7 cm (SD 1.7), but all of them managed to escape through the gap. A pot with a 2.5 cm escape gap caught only one *Acanthurus nigricauda* that was 26.1 cm long, and it did not escape. A pot with a 3.0 cm escape gap caught *Acanthurus nigricauda* with a total length ranging from 19.5 cm to 27.1 cm (SD 3.4), and out of those caught, fish with a total length ranging from 19.5 cm to 21.5 cm (SD 1.1) managed to escape.

A pot with a 2.0 cm escape gap caught *Acanthurus xanthopterus* fish that was 27.3 cm long, and it did not escape. A pot with a 2.5 cm escape gap caught *Acanthurus xanthopterus* fish with a total length ranging from 26.4 cm to 27.1 cm (SD 0.5), and none of them managed to escape. A pot with a 3.0 cm escape gap caught *Acanthurus xanthopterus* fish with a total length ranging from 21.8 cm to 29.1 cm (SD 5.2), and only fish with a total length of 21.8 cm managed to escape.

In this study, three dominant genera were examined to observe their behavior in relation to three different escape gap sizes. Among these genera, only the *Acanthurus reversus* species was caught in all three escape gap size treatments. The study analyzed the frequency of catching and escaping *Acanthurus reversus* based on the total length size classes. The findings of the study are presented in Figure 2. According to Figure 2 among the *Acanthurus reversus* fish, two size classes were caught and escaped but did not escape through the 2.0 cm escape gap. These size classes were 17-18 cm and 19-20 cm, while the size classes 25-26 cm and 26-27 cm did not pass through the 2.0 cm escape gap. On the other hand, the size class that was caught and passed through the 2.5 cm escape gap was 17-23 cm, while the 24-29 cm size class did not pass through the escape gap. Furthermore, the size class that was caught and passed through the 3.0 cm escape gap was 19-22 cm, while the 27-29 cm size class did not pass through the escape gap.

**The influence of differences in escape gaps on catch results**

**Friedman Test**

The results of the Friedman test (Table 4) indicate no significant difference between the number of fish that escaped through the three sizes of escape gaps tested ($\chi$r2 < $\chi$r2 α0.05).

Although the Friedman test results show no difference, Table 5 indicates that the average percentage of fish that escaped during 10 fishing trials tended to increase as the size of the escape gap increased. The larger the size of the escape gap, the more fish that are not yet catchable size can escape. The same thing was conveyed by Renchen *et al*. 2024, the use of escape gaps in pots can reduce the death rate of fish that are not yet suitable for catching. In this study, it was observed that the shape of the escape gap affects the escape behavior of fish. Fish species that are not suitable for catching and are typically caught as by-catch are able to escape through the escape gap. Similarly, dominant fish species that are not suitable for catching also manage to escape through the escape gap.

According to Barnes *et al*. (2022), pots with a rectangular release gap can reduce the number of small-sized catches by 92% compared to pots without a release gap. However, pots with a circular escape gap do not reduce unwanted catches. This is likely due to the behavior of the fish in the pot when it is lifted. The fish tend to swim vertically, which allows them to escape through the escape gap. One strategy for reducing bycatch is to retrofit pots with rectangular escape gaps, allowing juveniles and narrow-bodied species to escape (Rotherham *et al*. 2013).

**Escape gap selectivity**

Based on Figure 2, selectivity analysis was conducted on the size of *Acanthurus reversus* fish caught using escape gap pots of 2.0 and 3.0 cm. Figure 3 shows that the probability of catching and escaping fish of different sizes at escape gaps of 2.0 cm and 3.0 cm is different. For example, there is a 50% chance of catching fish with a total length in the range of 21-22 cm using an escape gap of 2.0 cm, while the escape gap size of 3.0 cm is suitable for fish in the range of 24-25 cm. If the escape gap size is 3.0 cm, the chance of catching Acanthurus reversus fish with a size range of

17-20 cm is very small, and the escape rate is very high.

Based on the analysis, it was found that escape gaps of 2.0 cm and 3.0 cm are effective in selectively catching *Acanthurus sp*. The graph indicates that the size class of Montana fish that achieved a selectivity value of 0.90 was between 28.5 – 30.5 cm, while the Gotana (*Acanthurus sp*) caught during fishing had a length of 27.3 – 29.1 cm, which is within the catchable category. This fish type has mature gonad size of 18.4 cm (length at first maturity). Selective pot fishing gear is designed to catch fish of an appropriate size and release those that are not yet suitable for catching, according to studies conducted by Kurniasih *et al*. (2016), Hehanussa *et al*. (2017), Mahiswara *et al*. (2018), and Hehanussa *et al*. (2020).

The research concluded that 27 types of fish and 1 type of *crustacean* were caught during the study. Fish pots fitted with an escape gap of 2.0 x 90 cm caught 19 species of fish, while an escape gap of 2.5 x 90 cm caught 16 species of fish and a gap of 3.0 x 90 cm caught 17 species of fish and 1 type of *crustacean*. The fish caught in pots with a 2.0 x 90 cm escape gap included ornamental fish from the *Chaetodon* genus, 3 types of fish with significant economic value (*rat grouper and black snapper*), and 13 types of coral fish for consumption. The catch from pots fitted with a 2.5 x 90 cm escape gap included ornamental fish from the *Chaetodon* genus, 2 types of fish with significant economic value (*rat grouper and red snapper*), and 11 types of coral fish for consumption. The pots fitted with a 3.0 x 90 cm escape gap caught ornamental fish from the *Chaetodon* genus, 2 types of fish with significant economic value (*rat grouper and finfish*), 1 type of crayfish (*Panulirus sp*), and 12 types of food reef fish.

Table 4 Friedman test for differences in the size of the escape gap on the number of fish that escape.

| **Trip** | **Treatment of Escape Gap Size** | | |
|---|---|---|---|
| | **2.0 cm** | **2.5 cm** | **3.0 cm** |
| 1 | 72.00 | 82.35 | 66.67 |
| Ranking | 2 | 3 | 1 |
| 2 | 50.00 | 66.67 | 100.00 |
| Ranking | 1 | 2 | 3 |
| 3 | 45.45 | 66.67 | 66.67 |
| Ranking | 1 | 2,5 | 2,5 |
| 4 | 66.67 | 40.00 | 25.00 |
| Ranking | 3 | 2 | 1 |
| 5 | 60.00 | 25.00 | 33.33 |
| Ranking | 3 | 1 | 2 |
| 6 | 33.33 | 60.00 | 50.00 |
| Ranking | 1 | 3 | 2 |
| 7 | 50.00 | 28.57 | 62.50 |
| Ranking | 2 | 1 | 3 |
| 8 | 16.67 | 20.00 | 27.27 |
| Ranking | 1 | 2 | 3 |
| 9 | 36.36 | 37.50 | 25.00 |
| Ranking | 2 | 3 | 1 |
| 10 | 50.00 | 58.33 | 75.00 |
| **Ranking** | **1** | **2** | **3** |
| **Number of rankings** | **17** | **21.5** | **21.5** |
| $\boldsymbol{\chi_r^2}$ | | **1.35** | |
| $\boldsymbol{\chi_r^2\ 0.05\ (db\ 2)}$ | | **5.99** | |

Table 5 Percentage of the number of fish that pass through the escape gap for each fishing trip.

| Trip | Treatment of Escape Gap Size | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2.0 cm | | | 2.5 cm | | | 3.0 cm | | |
| | *Catch* (Individual) | Get away (Individual) | % | *Catch* (Individual) | Get away (Individual) | % | *Catch* (Individual) | Get away (Individual) | % |
| 1 | 25 | 18 | 72.0 | 17.0 | 14.0 | 82.4 | 3.0 | 2.0 | 66.7 |
| 2 | 14 | 7 | 50.0 | 3.0 | 2.0 | 66.7 | 3.0 | 3.0 | 100.0 |
| 3 | 11 | 5` | 45.5 | 3.0 | 2.0 | 66.7 | 3.0 | 2.0 | 66.7 |
| 4 | 6 | 4 | 66.7 | 5.0 | 2.0 | 40.0 | 8.0 | 2.0 | 25.0 |
| 5 | 10 | 6 | 60.0 | 4.0 | 1.0 | 25.0 | 6.0 | 2.0 | 33.3 |
| 6 | 3 | 1 | 33.3 | 5.0 | 3.0 | 60.0 | 8.0 | 4.0 | 50.0 |
| 7 | 6 | 3 | 50.0 | 7.0 | 2.0 | 28.6 | 8.0 | 5.0 | 62.5 |
| 8 | 6 | 1 | 16.7 | 5.0 | 1.0 | 20.0 | 11.0 | 3.0 | 27.3 |
| 9 | 11 | 4 | 36.4 | 8.0 | 3.0 | 37.5 | 12.0 | 3.0 | 25.0 |
| 10 | 6 | 3 | 50.0 | 12.0 | 7.0 | 58.3 | 12.0 | 9.0 | 75.0 |
| **Average** | **9.8** | **5.2** | **48.0** | **6.9** | **3.7** | **48.5** | **7.4** | **3.5** | **53.1** |

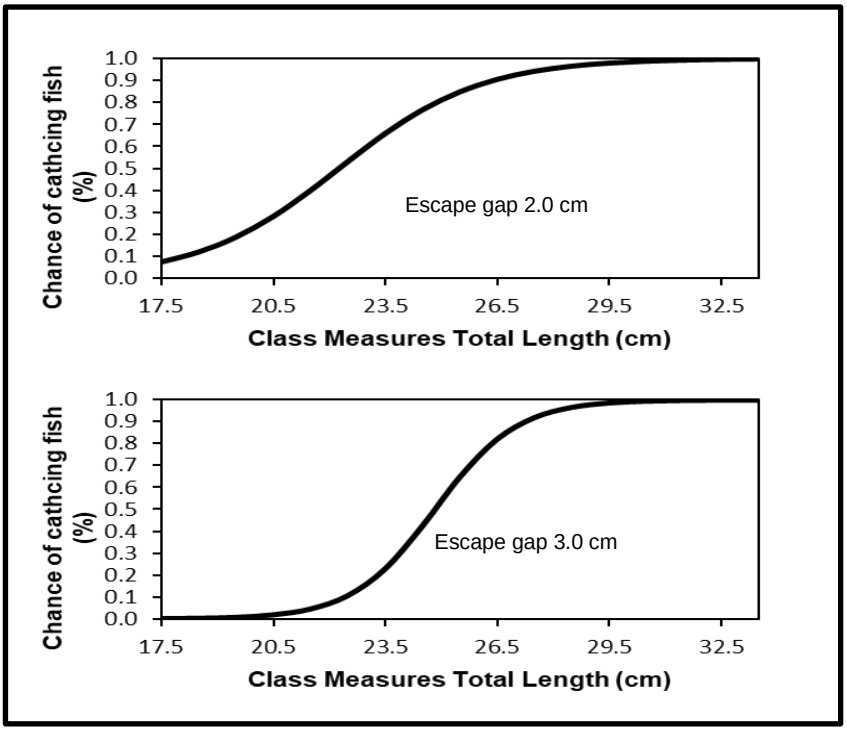


Figure 3 Logistic selectivity curve of the fish *Acanthurus reversus* with escape gaps of 2.0 cm and 3.0 cm.

The number of catches that passed the three escape gap sizes did not show any differences based on the Friedman test. However, there is a tendency that the larger the size of the escape gap, the average percentage of the number that escapes increases (Arana *et al*. 2011; Prakosa *et al*. 2017; Flower *et al.* 2021), in addition to the average size of the dominant fish caught. (*Acanthurus reverses*) that escaped increased. By placing pots at a depth of 5-10m, it was found that the dominant type of fish caught was *Acanthurus reversus*. This is to the habitat of this type of fish, namely coral reefs at a depth of 4-15m (Uejo *et al*. 2018). In Figure 3, logistics selectivity shows that the greater the chance of escape for the *Acanthurus reversus* fish catch, the higher the logistics selectivity. From the results obtained, it is known that the larger the size of the

escape gap, the greater the chance of the fish escaping, but if the size of a catch is too large than the size of the escape gap, then the chance of the fish escaping will decrease because it cannot escape through the escape gap. Broadhurst *et al*. 2020 suggest that adjusting the size of the escape gap for pots will result in positive selectivity. The same thing was conveyed by Butler *et al*. 2022 Pots with escape gaps can reduce catches of undersized fish, lowering mortality rates and preserving fish resources in the population.

In this study, the use of square-shaped escape gaps measuring 2 cm, 2.5 cm, and 3 cm on the bubu fishing gear was investigated. The study found that even though the escape gaps were expected to reduce the catch of fish that were not yet suitable for capture, the dominance of Botana fish (Acanthurus reversus) catches remained relatively high. This was due to the difficulty for flat-bodied fish, such as the Acanthurus reversus, to escape through the gap compared to other types of fish. The 2 cm escape gap allowed juvenile fish to escape, the 2.5 cm gap allowed slightly larger fish to escape, and the 3 cm gap ensured that only adult fish were caught. However, the flat body structure of the Botana fish affected the effectiveness of the escape gap. Therefore, further evaluation is necessary to determine whether the escape gap size and trap design are optimal for achieving the desired selectivity. Additionally, there is a need to consider the possibility of more appropriate gap designs and sizes for various reef fish species.

## CONCLUSION

Based on the results of the research conducted, it can be concluded that:

The following are the fish species caught with different escape gap sizes: - 2.0 cm escape gap size: 3 types of ornamental fish (*Chaetodon kleinii*, *Chaetodon selene*, *Chaetodon baronessa*), 13 types of coral fish for consumption, and 3 types of economically important fish (*Cromileptes altiveles*, *Scerus niger*, and *Epinephelus fuscogutatus*). – 2.5 cm escape gap size: 3 types of ornamental fish (*Chaetodon kleinii*, *Chaetodon selene*, and *Chaetodon baronessa*), 11 types of coral fish for consumption, and 2 types of economically important fish (*Cromileptes altiveles* and *Epinephelus fuscogutatus*). – 3.0 cm escape gap size: 3 types of ornamental fish (*Chaetodon kleinii*, *Chaetodon selene*, and *Chaetodon baronessa*), 12 types of coral fish for consumption, and 2 types of economically important fish (*Cromileptes altiveles* and *Epinephelus fuscogutatus*). Please note that the above data is based on the composition of fish species caught with different escape gap sizes. The size of the escape gap has no effect on the number of fish that escape through each escape gap. The opportunity to escape 50% of the size of the *Achanturus reversus* fish from the 2.0 cm escape gap is in the total length range of 21-22 cm, while from the 3.0 cm escape gap it is 24-25 cm.

## SUGGESTION

Based on the research findings, it is recommended that a 3.0 cm escape gap be installed in the pot. Further studies are required on species that hold significant economic value.

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## REFERENCES

Adyatma FN. 2020. Pengaruh Celah Pelolosan pada Bubu Lipat Tabung terhadap Hasil Tangkapan Ikan di Pantai Utara Kabupaten Tuban [dissertation]. Yogyakarta: Universitas Gadjah Mada.

Afoakwah R, Osei MBD, Effah E. 2018. A Guide on Illegal Fishing Activities in Ghana. *USAID/Ghana Sustainable Fisheries Management Project*. Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. Prepared by the University of Cape Coast, Ghana. GH2014_SCI048_UCC. 64: 1-55.

Arana PM, Orellana JC, De Caso Á. 2011. Escape Vents and Pot Selectivity in the Fishery for the Juan Fernández Rock Lobster (*Jasus frontalis*), Chile. *Journal of Fisheries Research*. 110(1): 1-9.

Barnes TC, Broadhurst MK, Johnson DD. 2022. Disparity Among Recommended and Adopted Escape-Gap Designs and Their Utility for Improving Selection in

an Australian Portunid Pot Fishery. *Fisheries Research*. 248: 106219.

Broadhurst MK, Millar RB, Hughes B. 2017. Performance of Industry-Developed Escape Gaps in Australian Portunus Pelagicus Pots. *Journal of Fisheries Research*. 187: 120-126.

Broadhurst MK, Tolhurst DJ, Hughes B, Raoult V, Smith TM, Gaston TF. 2020. Optimising Mesh Size with Escape Gaps in a Dual-Species Portunid-Pot Fishery. *Journal of Aquaculture and Fisheries journal*. 5(6): 308-316.

Butler CB, Butler J, Renchen GF, Hutchinson E, Matthews TR. 2022. Exploring the Potential use of Escape Gaps in the Florida Spiny Lobster, Panulirus argus, Fishery. *Journal of Fisheries Research*. 254: 106421.

Fachrussyah ZC, Zaman MSB. 2020. Kontruksi dan Rancang Bangun Bubu (*Fishing Pot*) dalam Upaya Peningkatan Hasil Tangkapan Ikan. *JAMBURA: Jurnal Ilmiah Manajemen dan Bisnis*. 3(2): 100-112.

Flower J, Estep A, James K, Ramdeen R, Runge A, Thomas L, Lester SE. 2021. An Experimental Evaluation of the Effect of Escape Gaps on the Quantity, Diversity, and Size of Fish Caught in Pots in Montserrat. *Plos One*. 16(12): e0261119.

Frandsen RP, Madsen N, Krag LA. 2010. Selectivity and Escapement Behaviour of Five Commercial Fishery Species in Standard Square and Diamond Mesh Codends. *Journal of Marine Science*. 67: 1721–1731.

Hehanussa KG, Martasuganda S, Riyanto M. 2017. Selektivitas Bubu Buton di Perairan Desa Wakal, Kabupaten Maluku Tengah. *Albacore Jurnal Penelitian Perikanan Laut*. 1(3): 309-320.

Hehanussa KG, Siahainenia SR, Paillin JB, Tawari RHS, Haruna H, Riyanto M. 2020. Kelangsungan Hidup Ikan setelah Meloloskan Diri pada Alat Tangkap Bubu di Perairan Desa Wakal, Kabupaten Maluku Tengah. *Jurnal Kelautan Tropis*. 23(2): 157-164.

Johnson AE. 2010. Reducing Bycatch in Coral Reef Pot Fisheries: Escape Gaps as a Step Towards Sustainability. *Marine Ecology Progress Series*. 415: 201-209.

Kurniasih A, Irnawati R, Susanto A. 2016. The Escape Gap Effectiveness of Collapsible Pot to Catch Swimming Crab (*Portunus pelagicus*) in Banten Bay. *Jurnal Perikanan dan Kelautan*. 6(2): 95-103.

Madsen N, Hansen KE, Poulsen T. 2001. The Kite Cover: a New Concept for Coverned Codend Selectivity Studies. *Journal of Fisheries Research*. 49(3): 219-226.

Mahiswara M, Hufiadi H, Baihaqi B, Budiarti TW. 2018. Pengaruh Ukuran Mata Jaring Bubu Lipat terhadap Jumlah dan Ukuran Hasil Tangkapan Rajungan di Perairan Utara Lamongan, Jawa Timur. *Jurnal Penelitian Perikanan Indonesia*. 24(3): 175-185.

Martasuganda S. 2008. *Bubu (Pots).* Departemen Pemanfaatan Sumberdaya Perikanan dan Pusat Kajian Sumberdaya Pesisir dan Lautan. Bogor: Institut Pertanian Bogor.

Mbaru EK, McClanahan TR. 2013. Escape Gaps in African Basket Pots Reduce Bycatch While Increasing Body Sizes and Incomes in a Heavily Fished Reef Lagoon. *Journal of Fisheries Research*. 148: 90-99.

Prakosa EF, Fitri ADP, Kurohman F. 2017. Analisis Celah Pelolosan pada Bubu Kubah terhadap Hasil Tangkapan Rajungan (*Portunus pelagicus*) di TPI Demaan Kabupaten Jepara. *Journal of Fisheries Resources Utilization Management and Technology*. 6(4): 103-109.

Rahman MA, Iranawati F, Sambah AB. 2021. Design and Effect of Escape Vent in a Pot on the Catch of Blue Swimming Crab (*Portunus pelagicus*): A Preliminary Study. *Research Journal of Life Science*. 8(1): 7-14.

Renchen GF, Butler CB, Hutchinson E, Matthews TR. 2024. Escape Gaps in Wire Lobster Pots Reduce Bycatch of Coral Reef Fish While Maintaining Catch of Harvestable Lobsters in Florida's Caribbean Spiny Lobster

(*Panulirus argus*), Fishery. *Fisheries Research*. 270: 106904.

Rotherham D, Johnson DD, Macbeth WG, Gray, CA. 2013. Escape Gaps as a Management Strategy for Reducing Bycatch in Net-Covered Pots for the Giant Mud Crab Scylla Serrata. *North American Journal of Fisheries Management*. 33(2): 307-317.

Sparre P, Venema SC. 1999. *Introduksi Pengkajian Stok Ikan Tropis*. Jakarta (ID): Pusat Penelitian dan Pengembangan Perikanan Badan Penelitian dan Pengembangan Pertanian.

Steel RGD, Torrie JH. 1993. *Prinsip dan Prosedur Statistika*. Edisi 2. Gramedia Pustaka Utama. Jakarta. 748 hlm.

Sudirman, Baskoro MS, Purbayanto A, Monintja DR, Arimoto T. 2014. Perfomans Selektivitas Alat Tangkap Bagan Ambo di Perairan Barru Selat Makasar. *Torani Unhas*. 14(1): 1-14.

Tallo I. 2015. Rancang Bangun Bubu Lipat dalam Upaya Peningkatan Efektivitas dan Efisiensi Penangkapan Kepiting Bakau yang Ramah Lingkungan [disertasi]. Bogor: Institut Pertanian Bogor

Tuhumury J, Hehanussa KG, Haruna H. 2022. Reconstruction of the Pot Fishing Gear Escape Gap Against the Catch. *Jurnal Agrikan (Agribisnis Perikanan)*. 15(2): 389-396.

Uejo T, Wibowo K, Motomura H. 2018. First Japanese Record of the Black Margined-Scale Sergeant Abudefduf Nigrimargo (*Perciformes: Pomacentridae*) from the Tokara Islands. *Species Diversity*. 23(2): 249-251.

Yusrizal. 2011. Perbandingan Penggunaan Ukuran Mata Jaring Bagian Kantong pada Trawl Dasar di Perairan Tanjung Kerawang [tesis]. Bogor: Institut Pertanian Bogor.