

## Determination of Minimum Mesh Size for Fishing Gear of the Indian Mackerel (*Rastrelliger kanagurta*) in North Maluku Waters, Indonesia

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### ABSTRACT

Regulation of the fishing net mesh size is imperative in implementing the ethical code of responsible fisheries. The fishing net mesh size should be defined based on the biological conditions of regional or local fish populations. This study aimed to estimate fish size at first gonadal maturity and analyze the minimum net mesh size for the Indian mackerel fishing gear in North Maluku Province, Indonesia. The research was conducted from January to June 2022 along the North Maluku waters. The fish length, body girth at first gonadal maturity and some aspects of mini purse seine fishing gear were addressed. The study results showed that the average total length at first gonadal maturity for the male fish was 24.27 and 24.01cm for the female fish. Moreover, the study results recommended that the maximum fish length of 24.27cm should be used to define the minimum net mesh size for the Indian mackerel fishing in the province. Further analysis assumed that the allowable minimum net mesh size for the mini purse seine main body and wings was 5.81cm (2.27 inches), while a mesh size of more than or equal to 2.54cm ( $\geq 1$  inches) should be used for bunt part.

### INTRODUCTION

The mackerel is a potential small pelagic fish commonly found in most Indonesian seas, including in North Maluku. The mackerel is a fish that has important economic value. This fish is easily caught in large quantities due to its schooling character (Prahadina *et al.*, 2015). One of the dominant species of the mackerel caught in the North Maluku waters is the Indian mackerel. This is indicated by the increasing of its production numbers from year to year.

The Indian mackerel fishing activities in North Maluku are generally carried out along the coastal sea using mini purse seines with various mesh sizes. The use of various net mesh sizes could have a negative impact since they may catch small fish or group of fish in their first gonadal maturity. This mackerel fishing condition occurs since the

fishing activities are still traditionally managed based on old customs. In other words, the mackerel fishing business in North Maluku is not yet supported by scientific data, information inputs, and proper management and administration. In the long run, this traditional fishing activity may cause an over exploitation and, subsequently the collapse of mackerel fish production of North Maluku Province.

Fishery management efforts can be more effectively and sustainably managed by utilizing scientific data and information, especially those derived from comprehensive studies on fish stock status and fish biology (**Zamroni & Suwarso, 2011**). For this reason, regulating the fishing net mesh size used to catch a certain species of fish is a must in implementing the ethical code of responsible fisheries (**FAO, 1995; Musbir *et al.*, 2006**). The determination of the mesh size should be based on the biological conditions of the fish stock in nature.

According to **Najamuddin *et al.* (2004)**, estimating the fish size at their first gonadal maturity is one way to determine population development stage in a certain area, such as time when fish are about to spawn, have just spawned, or have finished spawning. The decline of fish populations in the future can occur when a significant portion of the catch consists of fish that are about to spawn or have never spawned. Therefore, a critical preventive measure for fishing activity targeting a fish species is the proper regulation of fishing gear specifications.

The fish size at first gonadal maturity is vital information in implementing responsible fisheries. As a reference, the fish size at first gonadal maturity should receive more attention from policymakers so that there will be less concern about decreasing fish populations. Fish size at first gonadal maturity can be used as an indicator of fish reproductive stock availability. The fish body girth behind the operculum is used as a reference in determining the minimum mesh size (**Omar *et al.*, 2015**). The reason for applying the minimum fishing net mesh size for the Indian mackerel is to allow young and small fish to escape the fishing gear. Implementing this policy is necessary to ensure the sustainability of the Indian mackerel fishing in North Maluku, Indonesia.

## MATERIALS AND METHODS

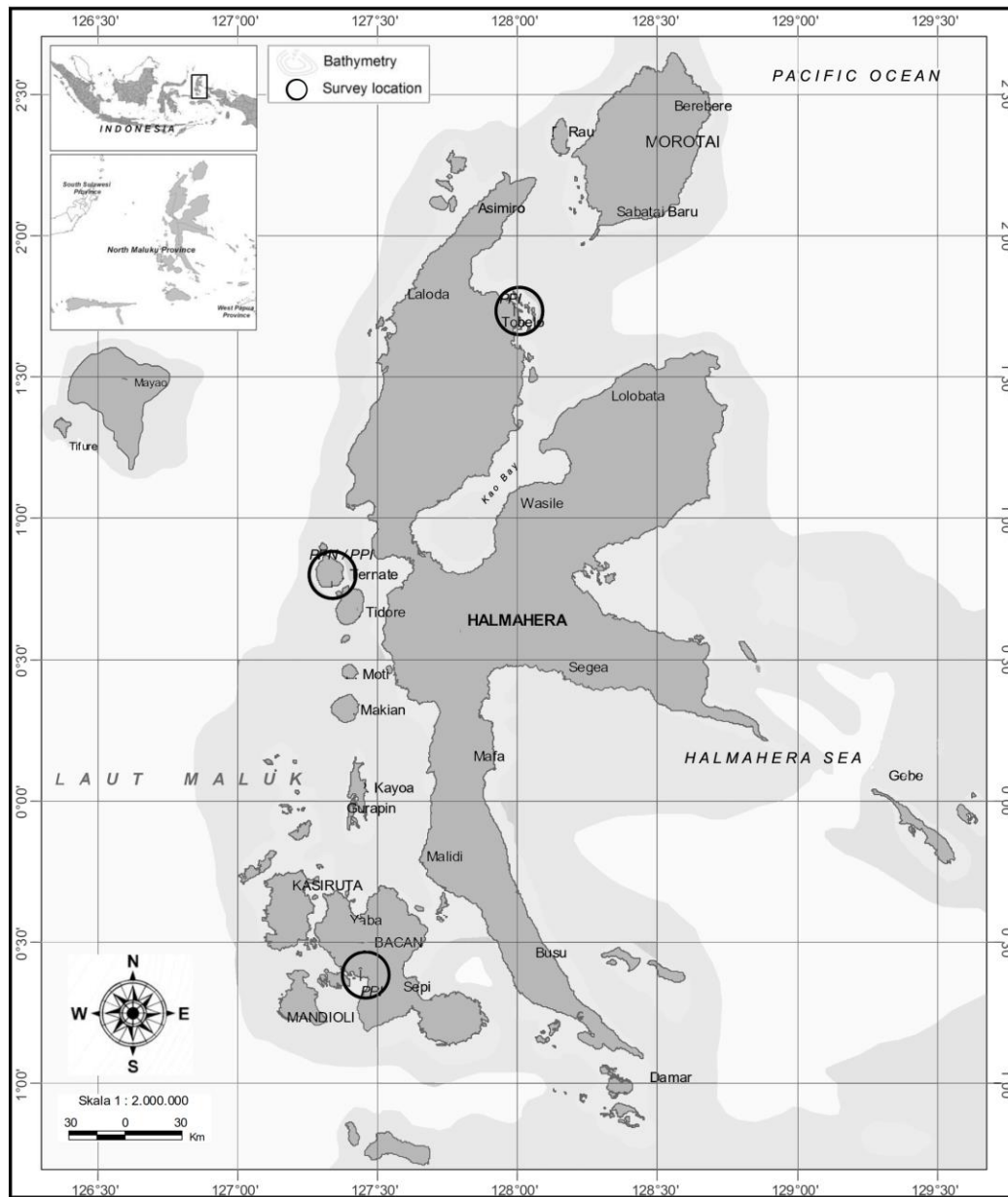
### 1. Study area

This research was conducted from January- June 2022. The location of fish sample data collection was all in North Maluku area (Fig. 1). All sample fish collected were caught by mini purse seine since they could provide fish in various sizes representing size or age structure of the Indian mackerel population of North Maluku.

### 2. Procedures

Fish samples were randomly collected from mini purse seine boats that landed their catches at the Ternate National Fishing Port with as many as 3,000 fish samples. From interviews with mini purse seine fishers, it was found that their fishing grounds

were mostly around the Ternate waters to the northern tip of the Halmahera Island, along the southern tip of the Halmahera Island to the western part of Bacan Island, and north of Morotai, as well as north of Kao Bay and its vicinity. Thus, the sample fish can represent the Indian mackerel populations of North Maluku waters.



**Fig. 1.** The map of research location

The minimum mesh size was determined based on a biological approach referring to the size of adult fish, namely fish that have spawned at least once. The minimum mesh size of the net was determined based on the fish total length (TL) and girth at first gonadal maturity.

### 3. Data analysis

The determination of the fish size at first gonadal maturity was analyzed based on the gonadal maturity level criteria of Cassie method modified by **Effendy (1997)**, **Najamuddin *et al.* (2004)** and **Zaki *et al.* (2016)**. Furthermore, the fish size at first gonadal maturity was determined by the Spearman-Kärber method (**Udupa, 1986; Kasmi, *et al.*, 2017**) with the following equation:

$$\log m = X_k + \frac{X}{2} - \left( \sum_{i=1}^n p \right)$$

Where,  $X_k$  = logarithm of the median value when the fish is 100% gonadal maturity;  $X$  = difference in the logarithm of the class mean;  $p = r/n$ ,  $r$  = number of gonadal mature fish in class  $i$ ;  $n$  = number of fish in class  $i$ , and  $q = i - p$ .

$$\text{Variety} = X^2 \sum \left[ \frac{p_i * q_i}{n_i - 1} \right]$$

The 95% confidence interval is:  $m \pm Z_{\alpha/2} \sqrt{\text{Var}(m)}$

This method aligns with the sigmoid curve method, with the distinction of mathematically calculating size ranges to enhance the accuracy and credibility of determining the reference size. Furthermore, the relationship between the body girth and total length of fish was analyzed using the simple linear regression of **Steel and Torrie (1981)** in **Nasution *et al.* (2015)** with the following equation:

$$Y = a + bX$$

Where,  $Y$  = fish length (cm), and  $X$  = body girth behind operculum (cm).

## RESULTS

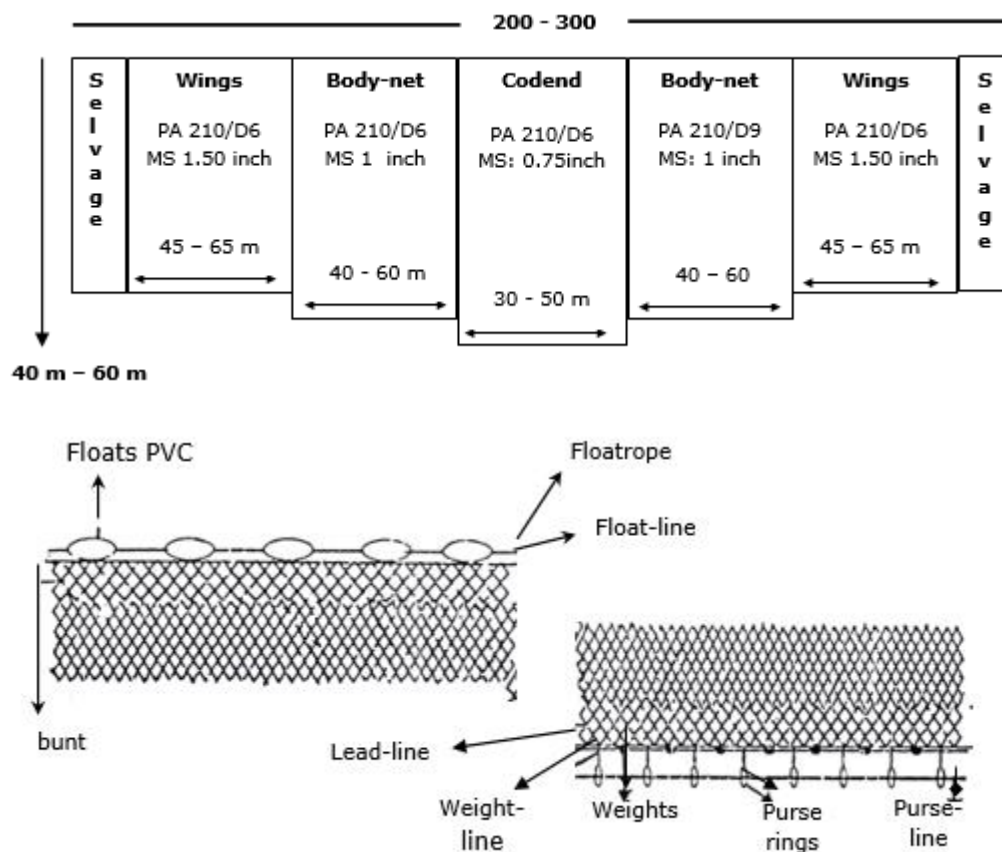
### 1. Construction of a mini purse seine in North Maluku

The Indian mackerel (*Rastrelliger kanagurta*) specimens in the North Maluku waters are predominantly caught using a mini purse seine. This fishing gear consists of bunt, codend, main body, wings, shoulder, floats-line, purse line, weights, buoys, and purse rings.

The length of the mini purse seine used in North Maluku ranges between 200 and 300m and the width ranges 40- 60m. The shoulder is a gathering place for fish made of PA 210/D12 with a mesh size of 0.75 inch. The main body-net is made of PA 210/D9 with a mesh size of 1 inch. The wing part that functions as a fence sometimes catches schools of fish and prevents fish from escaping. The codend is made of PA 210/D6 material with a mesh size of 1.50 inch. The shoulder is made of PVA 380/D15 with a mesh size of 1.50 inch consisting of 3 eyes for a downward direction. The float line is made of PVA material with a length of 410m and a rope diameter of 14 mm, and the lead line is made of PVA material with a rope diameter of 14mm and a length of 470m.

The amount of weights in a mini purse seine unit consists of 2200 pieces, weighing 100 grams/ piece. The weights on the purse seine are 2.9cm long and 2.8cm in diameter, made of lead. The distance between the ballast ranges from 10 to 15cm. The weight ropes for the purse seines are made of PVA material with a rope diameter of 12mm. The number of buoys in one purse seine unit consists of 1100 pieces, with a distance between the buoys of about 15- 20cm. The purse seine buoy has an elliptical shape with a length of 12.7cm and a diameter of 9.5cm made of synthetic rubber.

On average, the number of rings in one unit consists of 50 pieces. The rings used by purse seine fishermen in North Maluku have an outer diameter of 10cm and an inner diameter of 6.6cm. The rings used are brass, with a distance between the rings ranging from 5- 110m. The purse line on the purse seine is made of PVA material with a rope diameter of 20mm and a length of 600m. The construction of the mini purse seine can be seen in Fig. (2).



**Fig. 2.** Construction of a *mini purse seine* in North Maluku

## 2. Fish size at first gonadal maturity

Based on the results of the study, there were 3,000 Indian mackerel sample observed and measured, consisting of 1100 male and 1900 female. Male sample fish

length ranged from 20.50- 30.50cm TL and 21- 31cm TL for female fish. There was a difference in the fish size between male and female fish.

Male and female fish with gonadal maturity were 505 fish (45.89%) and 876 fish (46.11%), respectively. This showed that sample fish with immature gonads dominated the catch, namely 54% out of total 3,000 fish. A picture of the Indian mackerel observed is presented in Fig. (3).



**Fig. 3.** The Indian mackerel (*Rastrelliger kanagurta*)

The study result showed that the Indian mackerel male reach the first gonadal maturity at an average total length (TL) of 24.3cm with a range of 23.5– 24.4cm. Meanwhile, the Indian mackerel female reach first gonad maturity at an average total length of 24.0cm with a range of 23.7– 24.5cm. **Putera and Setyobudiandi (2019)** found that the male Indian mackerel reached the first gonadal maturity at an average length of 19.38cm, and for female it was 17.79cm. The total length at first maturity of the Indian mackerel in the Ambon Island was reported as 24.4cm (**Mosse & Hutubessy, 1996**). In the Flores Sea, females reached first maturity at 19.16cm FL (**Musbir *et al.*, 2006**), while in another study, females were observed to be 21.18cm FL and males 21.31cm FL (**Kasmi *et al.*, 2017**). In the Aru Islands, females were reported to reach the first maturity at 19.96cm FL (**Fauzi *et al.*, 2020**). Additionally, in a different study, females were reported to be 19.58cm TL (**Arrafi *et al.*, 2016**). According to **Rahardjo and Charles (2007)** and **Abubakar *et al.* (2019)**, differences in fish size at the first gonadal maturity can be influenced by changes in environmental conditions, abiotic factors, population genetics, water quality, and fishing pressure. Similiarly, **Agustina *et al.* (2015)** and **Widiyastuti *et al.* (2020)** stated that the differences in fish size at the first gonadal maturity found in various areas are influenced by many factors, such as water temperature, food, sex, hormones, and other seawater conditions. Likewise, **Siby *et al.* (2009)** argued that the variation in fish size at first gonadal maturity may be a reproductive response of fish to restore population balance, influenced by changing environmental conditions, abiotic factors, and overfishing.

Study data showed that there were 407 male fish (37%, out of 1100 fish samples) with a total length < 24.27cm. While for female fish, 570 fish (30%) out of 1900 sample had a total length <24.01cm. This data indicated that the Indian mackerel caught in the

research area was still dominated by fish having sizes larger than the size at the first gonadal maturity.

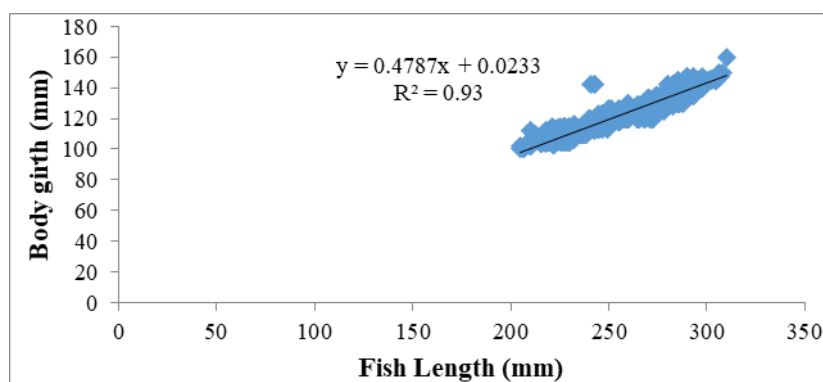
### 3. Determination of minimum mesh size

The net mesh size was determined based on a biological approach, referencing either the size of adult fish (those that have spawned at least once) or the size of fish at the first gonadal maturity. Therefore, the net mesh size was defined based on the total length and the body girth of the fish at first gonadal maturity. The length and body girth of the Indian mackerel at first gonad maturity found in the study are presented in Table (1).

**Table 1.** Data on length and body girth of the Indian mackerel at first gonadal maturity in North Maluku waters

Amount of fish sample	Total length(mm)	Body girth (mm)
1	205	102
2	215	104
3	217	105
4	220	106
5	223	108
.	.	.
.	.	.
.	.	.
3000	310	160

The calculation result for the relationship between body girth and fish length produced a linear relationship with a correlation coefficient of 0.96 and a determination coefficient of 0.93. The statistical model for the regression equation between fish length (X) and body girth (Y) was:  $Y = 0.0233 + 0.4787 X$ , as shown in Fig. (4).



**Fig. 4.** The relationship between body girth and length of the Indian mackerel

Based on the fish size at first gonadal maturity, the average total length for male fish was 243mm (24.27cm), and for female fish it was 240mm (24.01cm). As a cautions factor and population security, the upper limit (maximum) set up was 24.27cm for determining the fishing net mesh size. This length was substituted in the regression equation, and it gave the body girth value of 11.62cm. Hence, the optimum fishing net mesh size for the mini purse seine fishing gear for the Indian mackerel was 5.81cm or 2.29 inches.

Mini purse seine fishing gear used to catch the Indian mackerel in the North Maluku waters currently has a mesh size of 2.54– 3.80cm (1 – 1.5 inches) for the body and wings (selvage), while the mesh size for the pockets (bunt) is 1.90cm (0.75 inches). Thus, the mesh size of the fishing gear currently used for the Indian mackerel fishing is designed to prevent fish at the size of the first gonadal maturity and smaller from escaping. In other words, the currently used fishing net mesh size is not selective and may harm the fish stocks in the province. From the total sample data, the catch showed that 977 fish or 32.57% of the Indian mackerel were smaller than 24.27cm in total length. It showed that the catches obtained were dominated by fish that had spawned and about to first spawn. Biologically, this condition is quite good and supports the sustainability of the Indian mackerel population. However, to further maintain the sustainability of the Indian mackerel population and to implement responsible fisheries in North Maluku Province, it is necessary to apply regulation on the allowable minimum mesh size for mini purse seine fishing gear to prevent the catch of fish at first gonadal maturity size (total length < 24.27cm).

## DISCUSSION

Setting the minimum mesh size should be more strictly enforced on the body and wings (selvage) nets of the mini purse seine since these two parts made up to 80% of the fishing gear. As for the pockets (bunt), the minimum mesh size should be more than or equal to 1 inch, as regulated in the Indonesian Fishery Regulation (Decree of Marine and Fishery Ministry number 59 of 2020). The main goal of the re-adjustment of the net mesh size on the body and wings (selvages) was that fish at first gonadal maturity size and smaller could escape the fishing gear operation.

Improving the selectivity of fishing gear can be done by applying a minimum mesh size or by using a system of using certain nets with larger mesh sizes which function as a way for small fish to escape. According to **FAO (1995)** and **Warsa *et al.* (2020)**, information on the minimum mesh size is vital in implementing a ethical code for responsible fisheries. The mesh size gives an idea of the size of the fish to be caught. Anticipation for improving the purse seine selectivity can be in the form of applying an escaping window in the pocket of purse seine with square or hexagonal meshes. These techniques are commonly used in trawl and purse seine fishing (**Fonteyne & M'Rabet, 1992; Walsh *et al.*, 1992; Misund & Beltestady, 2000**).

According to the code of conduct for responsible fisheries (FAO, 1995), all fishing activities should be responsible to maintain the resources sustainability of its target. Sustainability of fisheries resources in a fishing ground will maintain the sustainability of fishermen business itself (Charles, 1994). The government as a controlling body for sustainable fisheries resources should ensure the balance between fisheries resources and their ecosystem.

Limiting the mesh size that can be used to catch certain species of fish is a must in implementing the ethical code of responsible fisheries. The mesh size should be determined based on the biological conditions of the fish in the field. The sustainable utilization of the Indian mackerel resources in the North Maluku waters highly depends on how the Indian mackerel resource is exploited. Therefore, it is necessary to use selective fishing gear capable of escaping fish of a specific size, that is, those that have never reached the gonadal maturity. This ensures that the fish caught have at least reproduced once in their lifetime.

## CONCLUSION

The study results showed that the size of the Indian mackerel at the first gonadal maturity had an average total length of 24.27cm for male and 24.01cm for female fish. The minimum mesh size of the mini purse seine that should be used is 5.81cm or 2.27 inches for the body and wings, while the mesh size for the bunt should be more than or equal to 2.54cm ( $\geq 1$  inch).

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