

Gillnet Selectivity and Mesh Size Regulation for Bali Sardine Fishery, (*Sardinella lemuru*) in Bali Strait

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ABSTRACT

Bali sardine resource in Bali Strait is abundant enough. However overfished of the resource has occurred due to excessive exploitation. Objective of this research was to determine the smallest mesh size of gillnet. Two different mesh sizes of the gillnet were used to define gear selectivity, namely 2.54 cm and 3.75 cm. Biological parameters to be examined were total length, body girth, body weight, sex, and gonad maturity. While length of frequency data was analyzed by applying the approach of normal distribution. In addition, the research applied curve selectivity approach to determine the smallest mesh size of fishing gear. Result showed that value selection factor (S) of the gear toward the fish was 5.89. While minimum mesh size of the gear to catch mature fish ($L_m \geq 17.1$ cm) was 2.94 cm. The research recommended that minimum mesh size of gillnet be at 2.94 cm and size of fish landed be higher than 17.3 cm.

Keywords: management effort, fishing gear, fish population dynamics, small pelagic.

INTRODUCTION

Amount of fish landed from Bali Strait during 1976-2008 was dominated by Bali sardine (*Sardinella lemuru*). Fish caught in that period reached about 541,538.6 ton/year. This was about 85% of total catch in average (Fisheries and Marine Board of East Java Province, 1977-2009). However the catch has been sharply declined in several year such as in 1986, 1987, 1992, 1996, 1999, and 2000. This is strong indication that overfishing of Bali sardine has occurred in Bali Strait [1] [2].

Excessive exploitation of mature and immature fish can cause the stock to be overfished. Two kinds of overfishing occurring in many waters were *growth over-fishing* and *recruitment over-fishing*. *Growth over-fishing* is a condition when the young fish are caught before reaching their maturity age [3][4]. While *recruitment over-fishing* is caused by excessive exploitation of mature and immature fishes. The latter will cause the occurrence of significant decreasing of mature fish. This situation will disturb stock recruitment due to limited number of mature and immature fish. Setyohadi *et al* [5] added that fishing toward young Bali sardine, called *sempenit*, occurred in Bali Strait. In addition, improper prediction toward status of the Bali sardine stock will cause over fishing even collapse of the stock.

The purpose of this study are as follow: 1) To identify biology parameter of Bali sardine (*Sardinella lemuru*) in Bali Strait, such as length of body girth, length at first mature (L_m), and length at first capture (L_c); 2) To illustrate gear selection factor of fish; and 3) To justify minimum mesh size of the net.

MATERIALS AND METHODS

This research was done in Bali Strait from September to December 2009. The research concentrated on biology aspect of Bali sardine and mesh size technology of gill net. Two kinds of mesh size were applied. They were 2.54 cm (gill net A) and 3.75 cm (gill net B). Data were obtained by conducting four times fishing trips done in Muncar waters (Annex 1). The catch was separately collected based on different mesh size of gear. Samples of fish of each fishing gear were about 20 kg which were randomly taken from fish landed. Measurements to be counted are total length, body weight, body girth, sex, and maturity of fish. Identification of fish was done based on Species Identification Sheet by Whitehead [6] and Pet, J.S. *et al* [7]. The data about biology parameter of the Bali sardine were based on Pet, J.S. *et al* [8] to analyse distribution of length frequency (LF) and maturity stage of fish.

Prediction of fish length at first mature (L_m) was calculated using logistic equation introduced by Sparre and Venema [9]:

$$Q = \frac{1}{(1 + e^{-a(L-L_{50})})} \dots\dots\dots (1)$$

Note: Q = Percentage of mature fish; L = mean length; L_{50} = length of 50% of mature fish; a = constant.

While length at first capture (L_c) was counted based on normal distribution of total length frequency [9]:

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Gear selectivity was predicted by using selectivity curve model whereas length distribution of fish was in accordance with normal curve [10]. Selection factor (S) was predicted using Sparre and Venema [9] equation below:

$$\ln\left(\frac{C_2}{C_1}\right) = a + b * L \dots\dots\dots (2)$$

Note: C_1 and C_2 = Amount of fish caught by gillnet in different mesh size m_1 and m_2 ; a , b = constant and slope; L = average class of length.

Selection factor could then be calculated using equation below:

$$S = -\frac{2a}{b(m_1 + m_2)} \dots\dots\dots (3)$$

Gear selectivity of each mesh size could also be predicted using this equation [11]:

$$L_c = S * m \dots\dots\dots (4)$$

Note: L_c = Length at first capture or optimum length of lemuru caught by gill net ; S = gear selection factor; m = mesh size.

Length at first mature (L_m) was used as substitution of optimum length (L_c) to decide the minimum mesh size of all net fishing gear. In addition, minimum mesh size of the net would be used to decide as minimum mesh size of gillnet

RESULT AND DISCUSSION

Length at first capture (L_c)

Result showed that average L_c of Gillnet A and Gillnet B is 15.66 cm and 18.02 cm respectively (Figure 1).

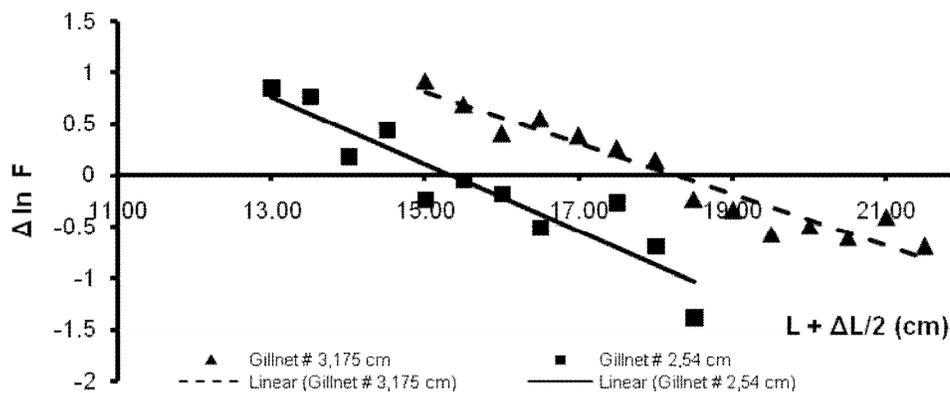


Figure 1 L_c of Bali sardine caught by gillnet A and gillnet B

Figure 1 illustrates that L_c of fish caught by both gillnet A and gillnet B is 15.66 cm and 18.02 cm respectively. Meanwhile previous research [2] found that L_c of fish caught by purse seine was only 14.3 cm. It can be concluded that both gears has high level of selectivity. This condition gives benefit for stock sustainability management.

Gear selectivity and minimum mesh size

Figure 2 illustrates that the average of total length of fish caught by gillnet B is much higher than the fish caught by gill net A. It is 18.1 cm and 15.6 cm respectively. The figure also informed that total length distribution of fish of both gears is overlapping. They overlap each other in modus between 14.25 cm to 19.25 cm.

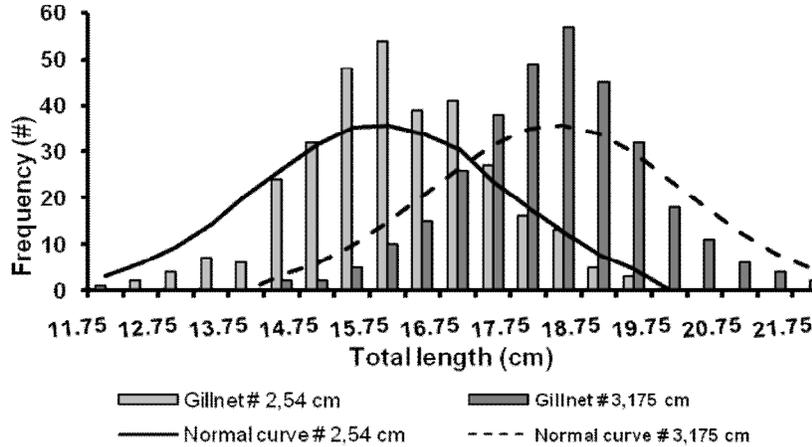


Figure 2 Length frequency of fish caught by gillnet A and gillnet B

By using equation 2, gear selectivity of gillnet can be calculated as below:

$$\ln\left(\frac{C_2}{C_1}\right) = -20,78 + 1,23 * L \quad (\text{Figure 3}).$$

Figure 3 also confirmed that gear selection factor (S) of the gillnet toward the catch is 5.89.

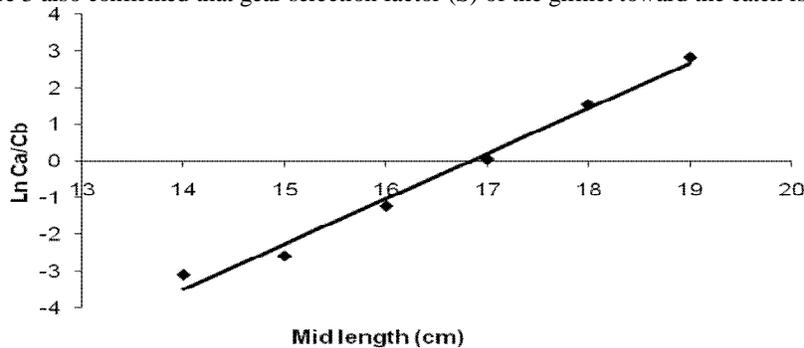


Figure 3 Gear selectivity analysis of the gillnet

Based on value of selection factor ($S = 5.89$), it is obtained that the size of optimum length (L_{opt}) of Bali sardine caught by gillnet A and B was 14.96 cm and 18.7 cm respectively. The higher the mesh size of the net is used, the longer the optimum length of the fish caught will be. This is in accordance with Gulland (1983). He stated that selectivity measurement of gillnet toward stock sustainability is based on value of fish length at first mature (L_m). Therefore fishing activity had to let 50% of mature fish back to fishing ground in order to give them chance to reproduce so that stock sustainability can be kept for future generation. It can be predicted that the use of gillnet A with mesh size of 2.54 cm would give bad effect on recruitment and stock sustainability which is known as growth overfishing. Whilst application of gillnet B with mesh size of 3.175 cm would give benefit to the stock sustainability management because amount of fish caught at first capture is higher than that of first mature. So that it will let fish to spawn before they are caught.

Data about fish at first mature (L_m) is used to calculate minimum mesh size of the net by applying equation 4 (Table 1).

Table 1. Selection factor, L_m , and minimum mesh size of the net

Sex	SF	L_m (cm)	Mesh size _{min} (cm)
Male	5.89	17.10	2.90
Female	5.89	17.50	2.97
Total	5.89	17.30	2.94

Size of fish length had a close relation with size of body girth while mesh size of the net directly influenced the size of fish body girth [12]. It was also reported that relationship between total length with body

girth (Lb) was defined as this linear equation: $Lb = 0.4640 L$ [2]. Average size of body girth of fish caught by gillnet A and gillnet B is 6.9 cm and 8.68 cm respectively. The size of body girth will be 8.07 cm when size of fish at first mature reaches 17.3 cm. In addition, the body girth of fish caught by purse seine is only 6.63 cm when the fish at first capture reaches at 14.3 cm in length.

Luccena *et al* [13] stated that due to the size of body girth of fish at the end of gill racker cup, which is smaller than mesh size of the net, the fish is easily to be tangled by gill net. They added that the range of average comparison between mesh size and body girth is about 1.0-1.1 and 1.3-1.4 respectively. Comparison between mesh size of the net and body girth of fish caught by gillnet A and gillnet B was 1 : 1.36 and 1 : 1.37 respectively. This fact illustrates that tangling is the most common way the fish to be caught by gill net.

Regulation of minimum mesh size of gillnet has to be applied in order to give chance for immature fish to get free. This will lead to immature fish able to spawn before they are caught. In other word, purpose of management mesh size is to ensure that the size of fish at first capture is higher than that of fish at first mature. Therefore sustainability of fish stock can be maintained for the future and continuation of fishing activity by fishermen will be ensured.

Mesh size of gillnet to catch fish at first capture (Lc) as same as at first mature (Lm = 17.3 cm) is 2.94 cm. Minimum mesh size of the net has therefore to be 2.94 cm. If minimum mesh size of the net is as wide as 2.94 cm, 50% of fish caught at first capture (Lc) will be 17.3 cm. Hence 50 % of immature fish will be able to escape. Then they are also able to spawn for producing young fish.

CONCLUSION

1. Size of first capture (Lc) of fish caught by gillnet A and gillnet B is 15.66 cm dan 18.02 cm respectively. While size of first mature (Lm) of fish is 17.3 cm.
2. Value of selection factor (S) of gillnet toward Bali sardine is 5.89. Therefore mesh size minimum of the net in order to catch fish at their first maturity (Lm) has to be 2.94 cm.

RECOMMENDATION

It is recommended that minimum mesh size of gillnet be at 2.94 cm and fish landed be higher than 17.3 cm.

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REFERENCES

1. Merta, I.G.S., K. Widana, Yunizal, and R. Basuki, 2000. Status of the Lemuru Fishery in Bali Strait Its Development and Prospects. Papers presented at the workshop on the fishery and management of Bali Sardinella (*Sardinella lemuru*) in Bali Strait. *FISHCODE MANAGEMENT*. FAO. Roma. P: 1-42.
2. Setyohadi, D., T.D. Lelono, A. Munthaha and Martinus, 2009. Stock Identification and Management Model of the Bali sardine (*Sardinella Lemuru*) in Bali Strait. *Research Report of National Strategic Fund Program*. Directorate General of Higher Education. National Education Ministry. Jakarta
3. Pauly, D., 1980. A Selection of Sample Method of The Stock Assessment of Tropical Fish Stock. FAO. *Fish. Circ. FIRM/C 729*, Rome. 54 pp
4. Pauly, D., 1984. 1984. Some Simple Methods for the Assessment of Tropical Fish Stock. *FAO Technical Papers* 234: 47.
5. Setyohadi, D., DO. Sutipto, and DGR. Wiadnya, 1998. Population Dynamic of the Bali sardine (*Sardinella lemuru*) and Its Management Alternative . *Journal of Botany Research*. Research Center of Brawijaya University. Vol. 10:1: 9104
6. Whitehead, P. J. P. 1985. FAO Species Catalogue. Vol. 7. Clupeid Fishes of the world. An Annotated and Illustrated Catalogue of the Herrings, Sardines, Pilchards, Sprats, Ancovies and Wolf Herrings. Part 1 Chirocentridae, Clupeidae and Pristigasteridae. *FAO Fish. Synop.*, 7(25) Pt. 1:303.

7. Pet, J.S., W.L.T. van Densen, M.A.M. Machiels, M. Sukkel, D. Setyohadi and A. Tumuljadi, 1997. Length Based Analysis of Population Dynamics And Stock Identification In The Sardin Fisheries Around East Java, Indonesia. *Fisheries Research* 31: 107-120
8. Pet, J.S., W.L.T. van Densen, M.A.M. Machiels, M. Sukkel, D. Setyohadi and A. Tumuljadi, 1997. Catch Effort And Sampling Strategies In The Highly Variable Sardin Fisheries Around East Java, Indonesia. *Fisheries Research* 31: 121-137.
9. Sparre, P and S.C Venema, 1998. Introduction to tropical fish stock assessment. Part 1: Manual. *FAO Fisheries Technical Paper* 306/1, Rev. 2.
10. Hovgard, H and H. Lassen. 2000. Manual on Estimation of Selectivity for Gillnet and Longline Gears in Abundance Surveys. *FAO Fisheries Technical Paper*. No. 397. Rome, FAO. 84p.
11. Millar, R. B., and Holst, R. 1997. Estimation of gillnet and hook selectivity using log-linear models. *ICES. J. Mar. Sci.* 54: 471-477.
12. Setyohadi, D., T.D. Lelono, and D.G.R. Wiadnya, 2005. *Fish Population Dynamic. Analytical Approach to Stock Prediction and Status of Capture Fisheries*. Fisheries Faculty of Brawijaya University. Malang
13. Lucena, F.M., C.M. O'Brien and E.G. Reis. 2000. The Effect Of Fish Morphology And Behaviour On The Efficiency Of Gill Nets, Their Selectivity And By-Catch: Two Examples From Southern Brazil. www.ices.dk/iceswork/2000/fullist.pdf. Tanggal Akses: 25 Juni 2006