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Bioeconomic Analysisis of Long-Jawed Mackerel Fish (*Rastrelliger* sp) in Indramayu Regency

Rizky Ferawati[1*], Zuzy Anna[1], Iwang Gumilar[1] and Achmad Rizal[1]

[1]Department of Fisheries, Faculty of Marines and Fisheries, Universitas Padjadjaran, Jl. Raya Bandung–Sumedang Km 21, Jatinangor 40600, Indonesia.

Authors' contributions

This work was carried out in collaboration among all authors. Author RF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ZA and IG managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Long jawed mackerel resources are resources that are open access and common resources. The activity of catch mackerel in Indramayu district is increasing every year. In 2018 total fish production was 8423 tons while in 2019 there were 9047 tons. The utilization of long jawed mackerel resources must be based on economic and biological aspects as well as planning a sustainable use of long jawed mackerel. This study aims to analyze the conditions, efforts, and actual production of bloating fishing activities that are sustainable and optimal in Indramayu, as well as providing input into the direction of appropriate input and output management in bloating fishing activities in Indramayu Regency. The study was conducted in December 2019 to January 2020. The method used in this study was a survey method using quantitative descriptive analysis. Sample included 100 patients (age range 15-65 years) with respondents were owner fishermen, crew members, and/or boat captains, respondents were fishing using payang and purse seine. The data analysis method used is Gordon Schaefer's bioeconomic analysis. The results of the study found that the recommended fishing effort was in Maximum Sustainable Yield (MSY) 100.061 trip conditions and total production of 9011 tons, Maximum Economic Yield (MEY) conditions 98.756

*Corresponding author: Email: rizkyferawati@gmail.com;

trips and total production of 9.009 tons, and Open Access (OA) conditions in 197.513 trips and total production of 4.638 tons. The condition of long jawed mackerel in Indramayu Regency has experienced biological overfishing and economical overfishing. The policy recommendation is a limited entry of 27.242 trips (MSY) to 28.547 trips (MEY). Presentation of the reduction in the number of payang and purse seine fishing gear fleets under the conditions of MSY was 58% and 91,3% while for the MEY conditions were 59% and 91,7%.

Keywords: Long jawed mackerel; Bioekonomi Indramayu; overfishing.

1. INTRODUCTION

Indramayu Regency as the first largest producer of capture fisheries in West Java. In 2017 has produced 134.713,49 tons or 64% of the total capture fisheries production in the North Coast of West Java [1]. This makes Indramayu Regency one of the most prominent areas in the marine fisheries subsector.

One of the fish caught in Indramayu regency is long jawed mackerel. Long jawed mackerel (*Rastrelliger* sp) is a small pelagic fish with high commercial value. This fish has a delicious taste. This fish is usually sold fresh or processed as boiled and salted fish and as fishing bait. *Rastrelliger kanagurta* was caught in the waters of Northeast Sumatra, West Kalimantan, Southeast Kalimantan, North Java and Eastern Indonesia [2].

Long jawed mackerel can caught every year in Indramayu Regency. Production of long jawed mackerel catch in 2015, 2016, 2017, 2018, and 2019 were 14.963 tons, 8.357 tons, 8.096 tons, 8.423 tons, and 9.047 tons [3]. Increased catch of long jawed mackerel is an important concern as we know that long jawed mackerel resources are open access and common resources that everyone has the right to use. This can cause a decrease in the number of catch of long jawed mackerel and a decrease in economic rent due to overfishing.

Utilization of fisheries resources must be based on socio-economic and biological aspects to support sustainable use activities [4]. Planning for sustainable use of long jawed mackerel must be carried out in order to maintain the availability of long jawed mackerel stock and fisherman income stability. This makes the importance of research on the Analysis of Bio-Economics of Long jawed mackerel (*Rastrelliger* sp) in Indramayu Regency.

The purpose of this study is to analyze the conditions, efforts and the actual production of sustainable and optimal long jawed mackerel fishing activities in Indramayu, and to provide recommendations on the proper management of inputs and outputs in the long jawed mackerel fishing activities in Indramayu Regency.

2. MATERIALS AND METHODS

This research was conducted in December 2019 to January 2020 in Indramayu Regency. The method used is a survey method using quantitative descriptive analysis. The data used uses primary data and secondary data. Primary data obtained through questionnaires and interviews with fishermen include data on sailing costs, fishermen income, the amount of time to sea, and other data. Secondary data was obtained through various relevant data sources in the form of reference books, literature or literature sources, scientific journals and information as well as data sourced from related agencies. These institutions such as the Department of Maritime Affairs and Fisheries of West Java Province and Indramayu Regency Fisheries and Marine Services.

Respondent sampling performed using purposive sampling method according to criteria. The sample criteria were: the respondents were owner fishermen, boat crew, and / or boat captains, the respondents caught fish using payang and purse seine. Respondents are able to communicate well and are willing to be interviewed.

2.1 Fishing Equipment Standardization

Fishing gear standardization is done to equalize its value in the ability to produce long jawed mackerel (*Rastrelliger* sp). Standard fishing gear is the dominant fishing gear that is used in long jawed mackerel fishing. The standardization of fishing gear uses the following formula [5]:

$$CPUE\ I: \frac{Ci}{fi}$$

CPUE S: $\frac{Cs}{Fs}$

FPIs= $\frac{CPUE\ i}{CPUE\ s}$ *=1*

Standard Effort = FPI * fi

Information:

CPUE I = Number of catch per unit effort of the I fishing gear unit

CPUE S= Number of catch per unit effort of a standard fishing gear

Cs = Number of catch of standard fishing gear

Ci = Number of catch of i-fishing gear

fs = Number of standard fishing gear capture effort

fi = Number of attempts to capture i-fishing gear

FPIs = Capability factor of standard type fishing gear

FPI = Capability factor of the i-fishing gear type

2.2 Catch per Unit Effort

Catch per unit effort (CPUE) aims to determine the abundance and utilization rates of long jawed mackerel. The formula calculates CPUE as follows [6]:

$$CPUE = \frac{Catch\ I}{Effort\ I}$$

Information:

CPUE = results per year of long jawed mackerel catch effort (kg / trip)

Catch I = catch of the i year long jawed mackerel (kg)

Effort I = Efforts to catch long jawed mackerel in the first year (trip)

2.3 Bioeconomic Analysis

The bioeconomic analysis basically uses two biological equations from the utilization of fish resources (population dynamics and fisheries production functions) combined with the equation of economic benefits. The production function is written in the following equation [7]:

h = q.E.x

The economic benefits of fishing are obtained through equations:

π = TR-TC

Or it can be solved into the following equation:

π = p.h-c.E

The bioeconomic analysis uses the Gordon Schaefer Model, as follows Table 1 [7].

Information:

h∞ = Catch on open-access condition

E∞ = Effort on open-access condition

π∞ =Economic rent on open access conditions

p = The price of long jawed mackerel (rupiah / kg)

c = capture costs (rupiah / trip)

α = interslope

β = slope

Table 1. Bio-economic analysis of Gordon Schaefer's model

Variable	MSY	MEY	OA
Production	$\frac{\alpha^2}{4\beta}$	$E_{MEY}\left(\frac{\alpha p + c}{2p}\right)$	$E_{MEY}\left(\frac{\alpha p + c}{2p}\right)$
Effort	$\frac{\alpha}{2\beta}$	$\frac{\alpha p - c}{2\beta p}$	$\frac{\alpha p - c}{2\beta p}$
Rente Economy	$p.\frac{\alpha^2}{4\beta} - c.\frac{\alpha}{2\beta}$	$p.h_{MEY} - c.E_{MEY}$	$p.h_{\infty} - c.E_{\infty}$

Source: Fauzi (2010)

3. RESULTS AND DISCUSSION

3.1 The Results of Long Jawed Mackerel Catching in Indramayu Regency in 2009-2019

The Results of Long Jawed Mackerel Catching in Indramayu Regency in 2009-2019 can be seen in Table 2 [3].

The activities of Long jawed mackerel catching using payang fishing gear got the highest yield in 2014 amounted to 14.612 tons. While the lowest yield of long jawed mackerel capture by using payang fishing gear in 2009 was 3.914 tons. The long jawed mackerel fishing activities using purse seine fishing gear get the highest yield in 2019 of 453 tons. While the lowest yield of long jawed mackerel capture by using purse seine fishing gear in 2009 was 167 tons. The catch of long jawed mackerel in Indramayu Regency has fluctuated from 2009-2019. Fluctuations in fish catch occur due to environmental, economic and fishermen factors [8].

3.2 Long Jawed Mackerel Effort per Type of Fishing Gear

Effort is a measurement of the number of types and variations of labor (human resources) and physical capital (man made capital) used as input [7]. These efforts are a measure of fishing activities carried out in a certain period of time called a trip. Long jawed mackerel fish effort can be seen in Table 3 [3].

Effort of long jawed mackerel using payang fishing gear in 2009 was 17.156 trips and in 2019 was as many as 112.850 trips. Highest Effort with payang fishing gear in 2017 was 123.393 trips and the lowest in 2009 was 17.156 trips. Meanwhile, long jawed mackerel effort using purse seine fishing gear in 2009 was 2.628 trips

Table 2. Total catch of long Jawed Mackerel in 2009-2019

Year	Production of Payang (Ton)	Production of Purse Seine (Ton)
2009	4163	3914
2010	4990	4691
2011	4797	4510
2012	5489	5159
2013	5539	5207
2014	15454	14612
2015	14963	14146
2016	8357	7859
2017	8096	7614
2018	8423	7921
2019	9047	8508

Source: Indramayu Regency Fisheries and Marine Services (2019)

Table 3. Capturing effort of puffed fish per type of fishing gear for 2009-2019

Year	Effort of Payang (Trip)	Effort of Purse Seine (Trip)
2009	17156	2628
2010	41961	2728
2011	62640	4488
2012	62640	8384
2013	91095	11917
2014	96780	14609
2015	100580	23384
2016	99504	22020
2017	123393	13812
2018	78784	11541
2019	112850	14454

Source: Indramayu Regency Fisheries and Marine Services (2019) and in 2019 as many as 14.454 trips. The highest effort in 2015 was 23.384 trips and the lowest in 2009 was 2.628 trips.

3.3 Catch per Effort

Catch per effort are obtained from the division between the production of long jawed mackerel (h) and effort (E). Catch per effort or commonly called Catch per Unit Effort illustrates the productivity value of the payang and purse seine fishing gear in its use to catch long jawed mackerel. The following is a comparison of the CPUE values between the payang and purse seine Fig. 1.

The catch per Effort of the payang and Purse Seine is very fluctuactive. The highest CPUE payang fishing gear value was in 2009 at 0,228 tons and the lowest in 2013 was 0,057 tons. While the highest CPUE Purse seine fishing gear value in 2010 was 0,0732 tons and the smallest CPUE value in 2013 was 0,0186 tons. The low CPUE value of a fishing gear is caused by the low catch of long jawed mackerel but the effort (E) by the fishermen is high [9].

The average CPUE value of payang fishing gear in the effort to catch long jawed mackerel is the highest. So the Payang fishing gear is a standard fishing gear. The CPUE value of the payang fishing gear made a linear graph with effort. From the linear graph the function y = -0,0009x + 180,11 is obtained. The function obtained is a negative function, which means that every addition of 1 unit of effort will reduce the CPUE value by 0,0009 kg. Based on the function equation, the coefficient α is 180, 11 and the slope (β) value is -0,0009.

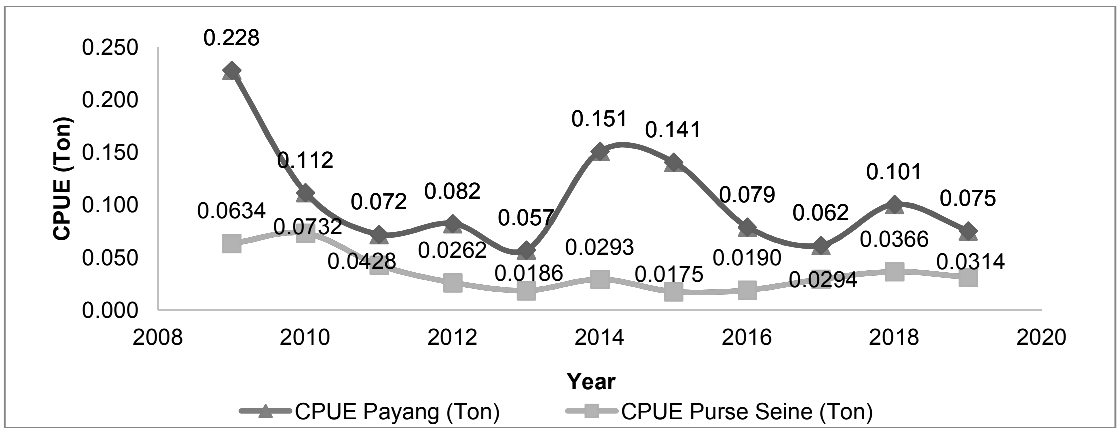

Fig. 1. Comparison CPUE payang and purse seine

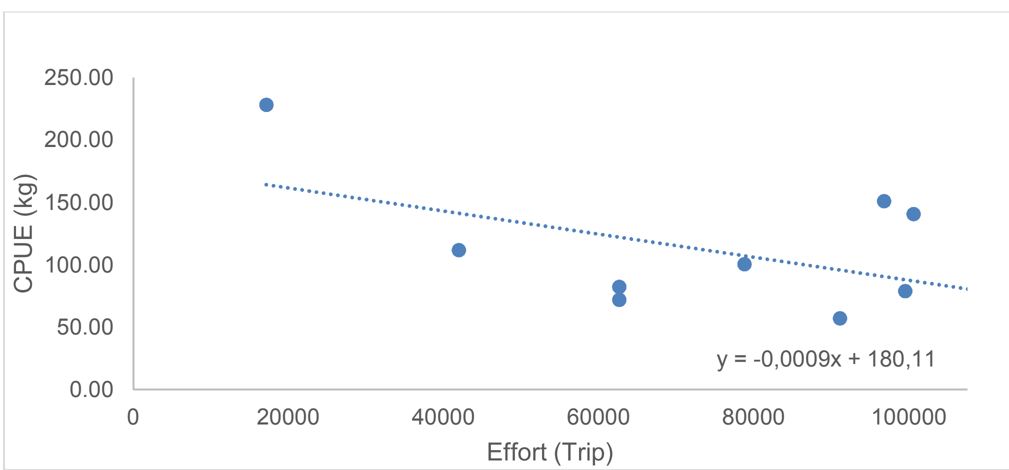

Fig. 2. Comparison CPUE and total trip

3.4 Sustainable Production Function

Based on the function equation, the coefficient α is 180,11 and the slope (β) value is -0,0009. Based on Fig. 3 the results of production under conditions of MSY is 9011 tons and effort under conditions of MSY is 100061 trips per year.

3.5 Bioeconomic Analysis

Bioeconomic analysis is a combination of the biological dynamics of fisheries resources and economic factors that affect capture fisheries [7]. This bioeconomic analysis was calculated by the Gordon-Schaefer model using three conditions namely Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access (OA). The results of bio-economic calculation of long jawed mackerel resources are presented in the Table 4.

Maximum Sustainable Yield (MSY) is an effort to capture fisheries resources appropriately to maintain the existence of fish stocks in the sea so that the sustainability of the stock can be maintained [10]. Long jawed mackerel catch under the conditions of MSY is 9011 tons and efforts carried out at 100.061 trips per year. The results of the calculation of profits in the MSY condition are no more profitable when compared to the MEY condition in the amount of Rp157.968.727.486 with a Total Revenue value of Rp162.198.060.500 and a Total Cost of Rp4.229.333.014. MSY value is the maximum value economically and socially [9].

The effort needed to reach the optimal point in the MEY condition is much smaller than in the MSY condition, so it can be seen that the level of effort at the MEY point is more conservative minded (more friendly to the environment) [11]. The calculation results in Table 1 show that effort in MEY conditions was 98.756 trips per year and the yield of long jawed mackerel catch was 9.009 tons. The total cost needed to catch long jawed mackerel within one year in the MEY condition is Rp.4.174.192.842. The total revenue obtained is Rp162.170.490.414. The profit gained from the difference between TC and TR values is Rp. 157.996.297.572. The total revenue obtained by fishermen is the total revenue in this MEY condition, which is not the highest but receives maximum economic rent. Maximum Economic Yield (MEY) is the maximum economic value in terms of fisheries resource management and business continuity by taking into account the sustainability of fish resources [12].

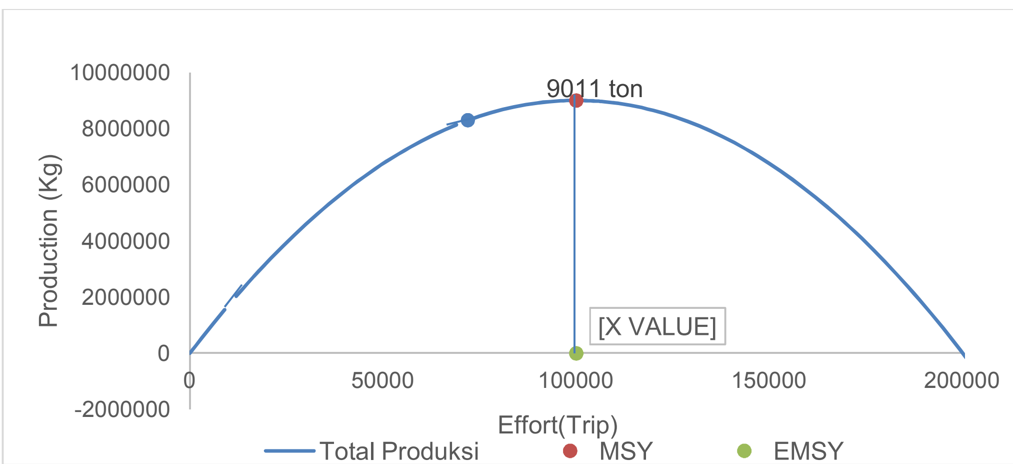

Fig. 3. Sustainable production function

Table 4. Bioeconomic analysis results of Long-Jawed Mackerel in various conditions

Variabel	Kondisi		
	MSY	**MEY**	**OA**
Effort (E)	100061	98756.56	197513.12
Catch (h) (Ton)	9011	9009	4638
TC (Rp)	Rp 4.229.333.014	Rp 4.174.192.842	Rp 8.348.385.685
TR (Rp)	Rp162.198.060.500	Rp162.170.490.414	Rp 8.348.385.685
Rente (π)	Rp157.968.727.486	Rp157.996.297.572	Rp

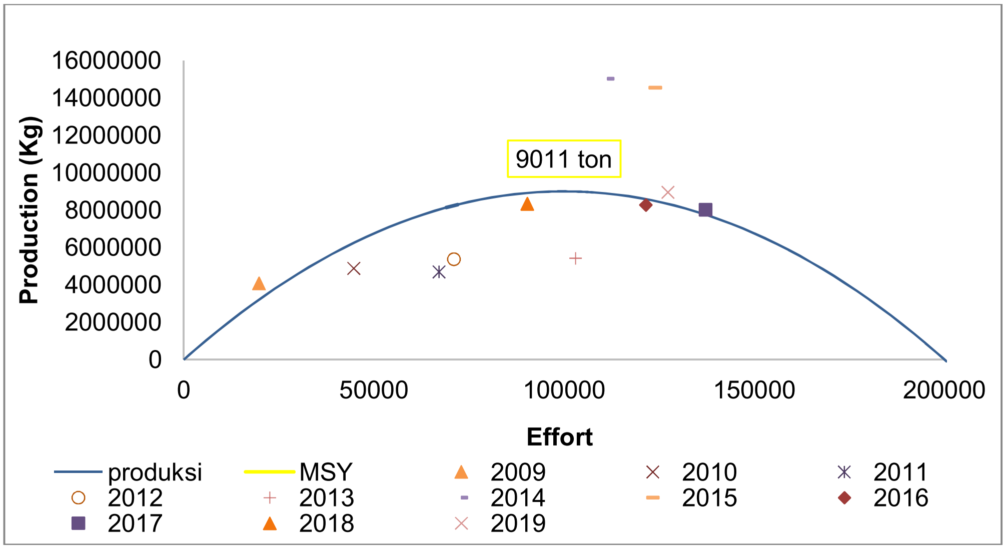

Fig. 4. Comparison of the MSY curve and actual production in 2009-2019

The open access condition is the balance point that occurs in bioeconomic analysis. The balance occurs at an effort level of 197.513 trips per year and the catch of long jawed mackerel is 4.638 tons per year. total cost of Rp8.348.385.685 with total revenue of Rp8.348.385.685. In other words, in this condition, long jawed mackerel fishing activities at the Indramayu DPI are no longer profitable.

A sustainable fisheries system is by limiting inputs and outputs in capture fisheries [13]. The results of this study of long jawed mackerel fishing are found to be some indication that the long jawed mackerel resources are being overfished. This is caused by the high exploitation of long jawed mackerel. Comparison of Sustainable Production Function Curve with Actual Production is seen in Fig. 4.

The results of the comparison of the MSY curve with the actual effort above are in the form of overlapping curves resulting in a contraction and expansion pattern in fishery utilization. Efforts for 2009, 2010, 2011, 2012 and 2018 have not exceeded MSY's limits in terms of production and number of trips. Effort in 2013, 2014, 2015, 2016, 2017 and 2019 has exceeded the MSY limit. In 2014, 2015, 2016, and 2017 the utilization status was outside the MSY boundary, resulting in biological overfishing. Biological overfishing has the potential to cause depletion and degradation of long jawed mackerel resources. Depletion is the rate of decline in resource stocks above the optimal rate of decline [10]. Meanwhile, degradation is a decrease in the quality / quantity of the environment due to suboptimal extraction and natural damage both naturally and artificially. In addition, from 2013, 2014, 2015, 2016, 2017, and 2019 there were efforts that exceeded the MSY limit so that the arrest yield also exceeded the MSY limit. Efforts that have exceeded MSY's efforts indicate that there has been an economic overfishing.

3.6 Recommendations on the Direction of Input and Output Management

a) Limitation of Input on Long jawed mackerel Fisheries

Monitoring of input factors can be done by using limited entry [14]. Calculation of limited entry by looking at the difference between the current actual effort and MSY's effort and also the difference between the current actual effort and MEY's effort.

Limited entry = Eactual – Emsy
= 127.304 trip – 100.061 trip
= 27.243 trip

Limited entry = Eactual – Emey
= 127.304 – 98.756trip
= 28.547 trip

The result of the Limited entry calculation above, can reduce the effort by 27.243 trips to 28.547 trips from the current actual effort. It is hoped that this reduction in effort so that long jawed mackerel in Indramayu can continue to be sustainable both biologically and economically.

b) Setting the Fleet Amount

The calculation of the fleet value and the ability of fishing gear in a certain period uses the following assumptions:

$$\frac{Total\ Armada}{Effort\ MSY/MEY} = \frac{Fleet\ n}{Proportion\ of\ effort}$$

$$\frac{Fleet\ n}{Actual\ effort} = \frac{Fleet\ estimation}{Proportion\ of\ effort}$$

The actual fleet of fishing gear is 1.562 units while the actual fleet of purse seine fishing gear is 325 units. The recommended number of fleets for payang fishing gear in MSY is 655 units. But for the MEY condition the recommended fleet number is 646 units. Then for purse seine fishing gear the recommended number of fleets in MSY conditions is 28 units. The recommended number of fleets for purse seine fishing gear in MEY conditions is 27 units.

c) Limitation on the Amount of Capture Allowed

The limitation on the number of catch allowed or total allowed catch (TAC) aims to make room for the resources of long jawed mackerel to recover so that long jawed mackerel activities can continue. How to calculate the TAC value in Indonesia is by multiplying the Hmsy value with 80%.

The number of catch allowed or total allowed catch (TAC) in long jawed mackerel fishing activities in Indramayu Regency is 7209 tons. Measures to limit the amount of catch allowed (TAC) are intended to approach and achieve complex steps so that the use of long jawed mackerel resources remains sustainable and continuous [15].

4. CONCLUSION

Based on the research regarding the bioeconomic analysis of long-jawed mackerel fish (*Rastrelliger* sp). Then it can be concluded that:

- The recommended effort under conditions of MSY is 100.061 trips and total production of 9011 tons with profits of Rp157.968.727.486, MEY conditions is 98.756 trips and total production of 9.009 tons with profts of Rp157.996.297.572 and OA conditions is 197.513 trips and total production of 4.638 tons and no profit.
- The condition of long jawed mackerel in Indramayu Regency has experienced biological overfishing and economical overfishing.
- The policy recommendation is limited entry of 27.242 trips (MSY) to 28.547 trips (MEY). Percentage of the reduction in the number of payang and purse seine fishing gear fleets under the conditions of MSY was 58% and 91,3% while for MEY conditions was 59% and 91,7%.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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