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Bioeconomic analysis of mackerel resources management (*Rastrelliger* sp.) at Malacca Strait, Serdang Bedagai Regency, Sumatera Utara

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Abstract. Mackerel (*Rastrelliger* sp.) is one of the main catch fisheries at Malacca Strait Serdang Bedagai, Sumatera Utara. This research aims to estimate mackerel (*Rastrelliger* sp.) resource potential with a bioeconomic model for mackerel resources sustainability landed at Tanjung Beringin. This research was conducted in July – September 2021. The method of research used the purposive sampling method. The surplus production method to estimate the Maximum Sustainable Potential (MSY) and the Gordon Schaefer Bioeconomic Model. The total sample fish of Indian mackerel were 272 individuals. The research showed bioeconomic analysis with Schaefer's surplus production model approach shows that the optimum production rate is 359 tons and the optimum effort is 12148 trips. The Mackerel resources indicate to be biological overfishing.

1. Introduction

Serdang Bedagai Regency has a coastline of about 95 km and five sub-districts including Tanjung Beringin where most people work as fishermen. However, capture fisheries activities are still dominated by small-scale fishing using dredges, purse seines, gillnets, line fishing, and seine nets. This is evidenced by data in 2020, where the entire fleet of fishing vessels in Serdang Bedagai Regency is 2,941 units, consisting of 2,871 motorized boats and 70 non-motorized boats [1].

The mackerel is a pelagic fish that lives in both coastal and offshore groups. Mackerel eats plankton such as detritus and filamentous algae [2]. Mackerel is often caught with several fishing gears, one of which is a fishing gear with a low selectivity level so the by-catch results vary. In addition, young mackerel and mackerel that are gonadal ripe are also often caught, so it is feared that it will interfere with the recruitment of these fish in nature because the fish do not have the opportunity to spawn at least once in their life cycle [3].

Increased demand for fish followed by a continuous increase in production can lead to overfishing. This condition will lead to a decrease in the stock (stock depletion) of mackerel which has an impact drastically reducing the catch of mackerel and the maximum profit received by fishermen. One way to reduce the impact of overfishing is to limit catch efforts by analyzing the potential from fisheries biological and economic aspects so that mackerel stocks can be managed sustainably.

2. Materials and methods

2.1. Research site
This study was carried out in July – September 2021 in Malacca Strait, Serdang Bedagai District, Sumatera Utara (Figure 1).

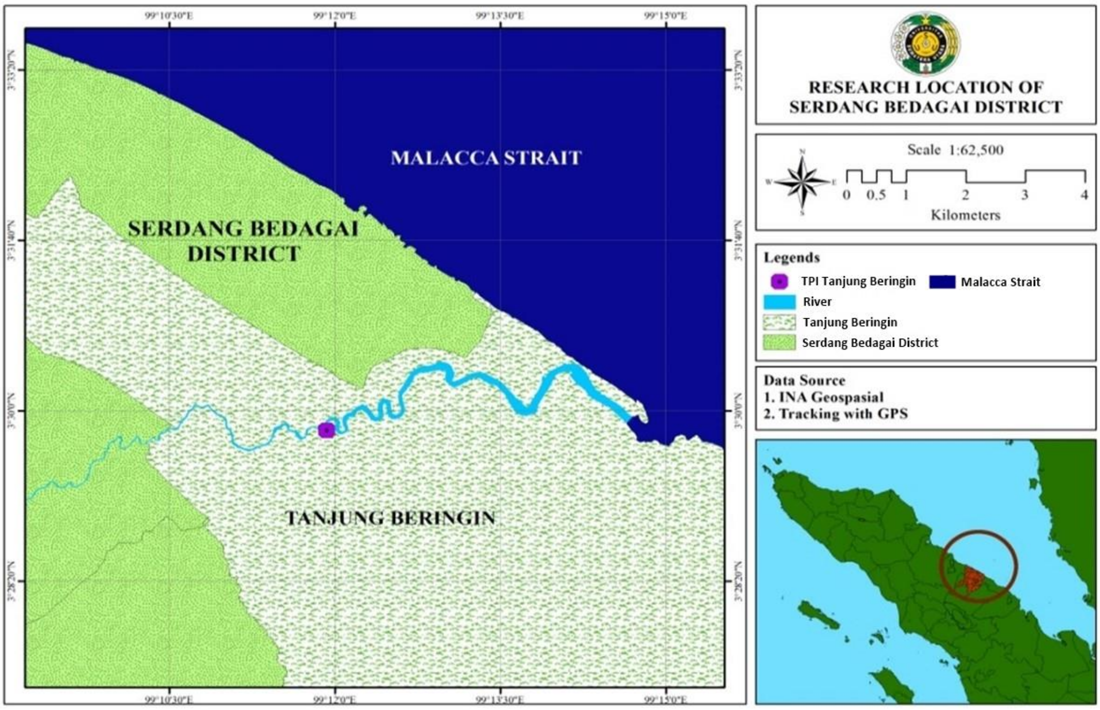

Figure 1. Research site in Serdang Bedagai District.

2.2. Procedures
The data were collected by purposive sampling, namely data collection was carried out intentionally from mackerel fishermen who would be studied as respondents. Determination of respondents in accordance with the desired conditions and the existence of good communication skills in filling out the questionnaire. The formula Slovin method can determine the number of samples with a 90% of confidence level [4] as:

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

Descriptions:
n = size of a sample
N = size of population
e = fault tolerance limit

2.3. Analysis of data

2.3.1. Standardize the fishing gear. According to [5], standardization of fishing gear needs to be done because the Mackerel (*Rastrelliger* sp.) is caught using more than one type of fishing gear in 2 steps: 1) the fishing gear that is used the standard is selected fishing gear that has complete data in time series and has CPUE largest; 2) calculate the FPI of each fishing gear provided that the FPI value of the fishing gear that is used as the standard is 1, while the FPI of other fishing gear varies with the standard fishing gear used as a comparison. The FPI value can be obtained with the equation:

$$\text{CPUE r} = \frac{\text{Catch r}}{\text{Effort r}} \tag{2}$$

$$\text{CPUE s} = \frac{\text{Catch s}}{\text{Effort s}} \tag{3}$$

$$\text{FPI}_\text{i} = \frac{\text{CPUE}_\text{r}}{\text{CPUE}_\text{s}} \tag{4}$$

Descriptions:
CPUE r = total catch per standardized gear of catch
CPUE s = total catch per standardized fishing gear of effort
FPI i = fishing gear of fishing Power Index to i = 1,2, 3,….k

2.3.2. Gordon-Schaefer bioeconomic analysis. According to [6], the economic aspects that are taken into account are the price and cost factors. In the Gordon-Schaefer assumption that only fishing factors are considered, so that the intended fishing cost is the total expenditure of the average fishing unit, including operating costs per year per unit of standard fishing gear.

$$c' = \frac{\sum c'i}{n} \tag{5}$$

Descriptions:
c' = Average fishing cost (IDR/trip)
c'i = Nominal arrest fee of its respondent
n = Number of respondents

Furthermore, the price of fish is determined from the average price of the catch.

$$p = \frac{\sum \text{Pi}}{n} \tag{6}$$

Descriptions:
p = Average price of fish (IDR/kg)
pi = Nominal price of the i-year
n = Number of respondents

Table 1. Bioeconomic analysis of Gordon Schaefer's model.

variables	MSY	MEY	OAE
Catch	$\frac{\alpha^2}{4\beta}$	$\alpha E_{MEY} - \beta(e_{MEY})^2$	$\alpha E_{OAE} - \beta(e_{OAE})^2$
Effort	$\frac{\alpha}{2\beta}$	$\frac{(p\alpha - c)}{(2p\beta)}$	$\frac{(p\alpha - c)}{(p\beta)}$
Total Receipts	C_{MSY} x p	C_{MEY} x p	C_{OAE} x p
Total Expenditure	C x E_{MSY}	C x E_{MEY}	C x E_{OAE}
Advantage	$TR_{MSY} - TC_{MSY}$	$TR_{MEY} - TC_{MEY}$	$TR_{OAE} - TC_{OAE}$

Description:
α = intercept

β = slope
p = price
c = cost
TR = Total Receipts
TC = Total Expenditure
E = Effort
MSY = maximum sustainable yield
MEY = maximum economic yield
OAE = open access

3. Results and discussion

3.1 Mackerel production
Mackerel production at Malacca Strait was the lowest in 2016 at 60.652 tons. Then in the following year it continued to increase until the highest catch in 2020 was 292.940 tons. The increase in the catch of mackerel at Malacca Strait, Serdang Bedagai Regency, is accompanied by an increasing effort to catch fish from year to year. According to [7], fluctuations in catches of mackerel are influenced by the total of fishing efforts, the appearance of fish, and the fishing operations of success rate.

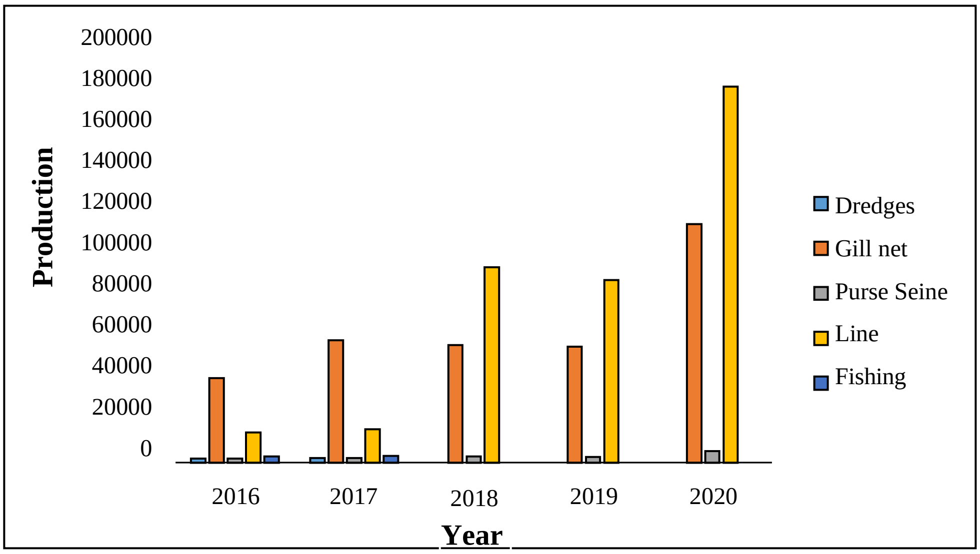

Figure 2. Production of mackerel per fishing gear at Malacca strait in 2016-2020.

The effort of mackerel in 2019 decreased slightly compared to the previous year, but this year there was an increase in fishing effort, so it can be assumed that increased competition between fishermen when catching fish was accompanied by increased fishing efforts. This is in accordance with [8] which states that the number of fishing efforts made in previous years can increase the level of competition between fishermen so that catches also decrease. In addition, the increased catches occur due to an increase in total of fishing trips, but it must be supported by the conditions of the right fishing area as well so that the catch does not decrease.

3.2 Effort of mackerel in Malacca strait
Based on the amount of effort for each fishing gear, gillnets had the highest effort in 2016 and 2017. However, from 2018 to 2020, the highest effort was using line fishing gear. Meanwhile, the lowest effort value from 2016 to 2020 is purse seine as shown in Figure 4.

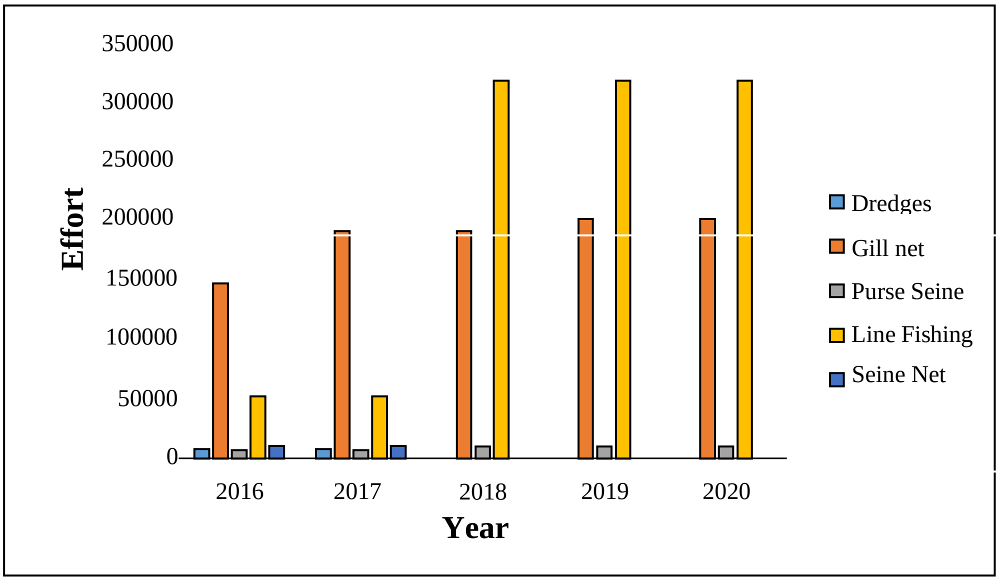

Figure 3. Effort of mackerel per fishing gear at Malacca strait in 2016-2020.

Efforts of mackerel always increase every next year. The lowest fishing effort occurred in 2016 with a total of 221280 trips, while the highest effort was in 2019 and 2020, each with 519840 trips. The increase in the fishing effort every year is caused by the increasing number of vessels and fishing gear used to catch mackerel. Thus, in 2019 and 2020 a large number of fishing efforts will have a negative impact on mackerel resources in the waters of Serdang Bedagai. This is in accordance with [9] which states that a fishing effort (effort) that is too large can have a negative impact on the condition of the catch or stock of fish resources in the waters due to an imbalance between fishing effort and the condition of available fish resources.

Weather is also one of the obstacles faced by fishermen, bad weather often prevents fishermen from making catching. As a result, fishermen get very few catches, thus making mackerel fishing trips less efficient. Then if there is bad weather, fishermen automatically cannot go to sea because of high waves. Fishermen also cannot determine fishing areas when the weather is bad because fishermen only use fishing methods that have been passed down from generation to generation or only use instinct and experience. But some ships use tools to find schools of fish (Fish finder), GPS, and other navigation tools. According to [10], decreasing and increasing a fishing effort is not always followed by an increase in production and vice versa. This incident shows that the increase in the number of fishing efforts is not the only factor causing the decline in catches but is influenced by several factors such as fishing season and changes in weather that can affect the abundance of fish.

3.3 Catch per unit effort, MSY, and optimum effort

In 2019, the value of the lowest CPUE was 0.033 and the highest CPUE value was 0.052 in 2017. The total production, trips, and standard purse seine of CPUE can be seen in Table 2.

In 2019, The lowest CPUE value was 0.033 with an effort of 9840 trips. The highest CPUE value occurred in 2017 which was 0.525 with an effort value of 6960 trips and in other years it fluctuated. With the fluctuation of the CPUE value obtained, it is necessary to know the relationship between the CPUE value with effort and catch. By knowing the CPUE value, the productivity trend of the existing fishing gear can be known within a certain period of time. [6] said that at the beginning of the arrest, the CPUE value increased due to the increase in effort, and then there would be a decrease in the CPUE value. This is due to the increasing operation of fishing gear and competition where the resource capacity is limited and tends to decrease due to continuous fishing density.

Table 2. Total production, trip, and CPUE of Purse Seine.

Year	Production (ton)	*Effort* (Trip)	CPUE	Ln CPUE
2016	1907.72	6960	0.047	-3.052
2017	2120.56	6960	0.052	-2.946
2018	2879.81	9840	0.035	-3.332
2019	2696.26	9840	0.033	-3.398
2020	5545.04	9840	0.037	-3.292

Based on the table of the CPUE value of mackerel landed at Malacca Strait, it tends to decrease from 2018-2020, this indicates that the waters of Serdang Bedagai Regency have experienced overfishing. This is in accordance with [11] which states that one of the characteristics of overfishing is a fluctuating or erratic catch graph in time units and a significant decrease in production, saying that more frequent fishing events can be detected by decreasing catch per unit effort (CPUE) and decreasing total catch landing.

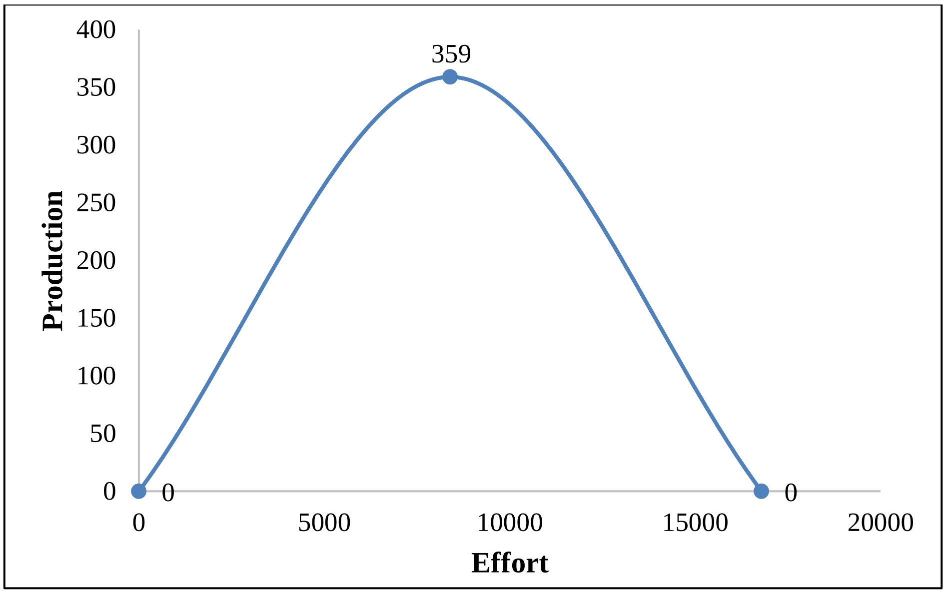

Figure 4. The maximum sustainable yield for mackerel at Malacca strait.

The Maximum Sustainable Yield for mackerel at Malacca Strait from 2016-2020 is 359 tons/year which can be interpreted as an estimate of the maximum catch that can be done to maintain the sustainability of mackerel (*Rastrelliger* sp.) resources in the waters. This is in accordance with [12] which states that the Maximum Sustainable Yield (MSY) is the largest catch that can be produced from year to year by a fishery.

3.4 Bioeconomic analysis

The Gordon Schaefer bioeconomic model by Purse Seine data from 2016 to 2020 data, it is known that the results values of the mackerel's MSY, MEY, and OAE in Malacca Strait, Serdang Bedagai Regency, can be explain in Table 3.

The bioeconomic model of result on activities of MEY obtained catches of 328 tons/trip and 6,074 trips/year of the number of fishing trips will result in an income or TR of IDR 8,182,556,434 with capital costs incurred or TC of IDR 3,439,679,800 so the profit with economic rent is IDR 4,742,876,634 and the results of bioeconomic activities at the maximum sustainable yield are 359 tons/trip of catch with

8,456 trips/year of fishing trips. will get an income or TR of IDR 8,902,323,108 rupiah with the capital costs incurred or a total cost of IDR 4,879,213,147 so a profit of IDR 4,023,109,960 is obtained, while in open fishing conditions or activities. access) the results obtained are 282 tons/trip with the number of fishing trips s a total of 12,148 trips/year where the total revenue obtained is IDR 6,879,359,601 and the total costs incurred are the same as the total revenue, which is IDR 6,879,359,601 so the profit obtained on open access activities is IDR 0 rupiah or neither gain nor loss. This is in accordance with [6] which states that if each level of effort is lower than the open access fishing effort, the total revenue will exceed the total cost so that fishery behavior will be more interested in catching fish. In conditions of open access without being controlled, this will cause many new players to enter the fishing industry. On the other hand, many actors leave the fishing industry at a level of effort that is higher than the total cost.

Table 3. Bioeconomic analysis of mackerel at Malacca strait.

Activity	C (ton)	Trip	TR	TC	Advantage
MEY	328	6,074	IDR 8,182,556,434	IDR 3,439,679,800	IDR 4,742,876,634
MSY	359	8,456	IDR 8,902,323,108	IDR 4,879,213,147	IDR 4,023,109,960
OAE	282	12,148	IDR 6,879,359,601	IDR 6,879,359,601	-

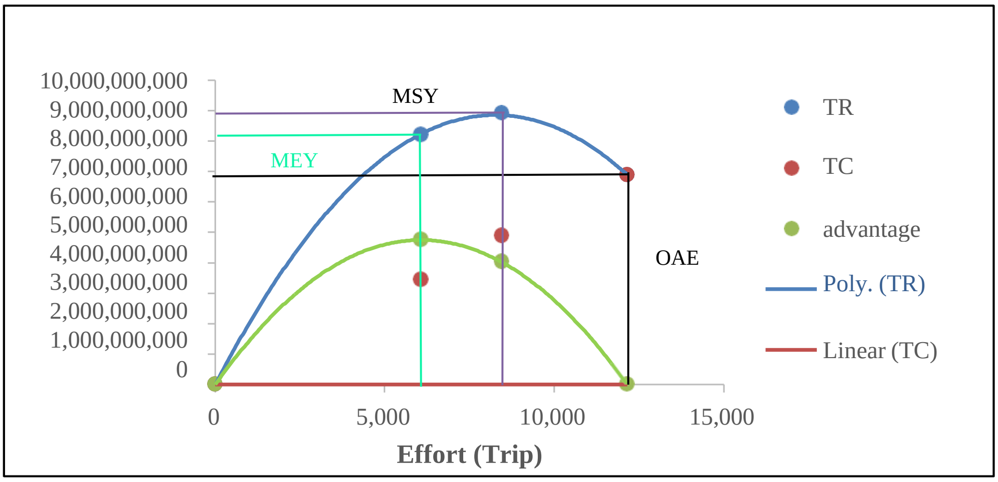

Figure 5. Mackerel of MSY, MEY, and OAE curves.

In the open access zone, the balance occurs at point C where the difference between total revenue and the total cost is zero or also known as the break-even point or BEP (Break Even Point), where if you continue to force it, it will cause fishing activities to be in adverse conditions (TR < TC). According to [13] which states that the Break-Even Point (BEP) is a condition in which a company neither gains nor loses. Break-even points provide information about the break-even position, but break-even points are very helpful for management in planning and decision-making.

4. Conclusions

The estimation of the potential utilization of mackerel resources at Malacca Strait, Serdang Bedagai Regency was carried out using the Schaefer model in the MSY, MEY, and OA management regimes, with a maximum effort of 12,148 trips, an optimum catch of 359 tons, and an economic rent or optimum profit of IDR 4,742,876,634. Management is carried out through the MEY approach using two options, namely reducing inefficient fishing trips and reducing the number of purse seine vessels with a non-buyback system.

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