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BIOECONOMIC ANALYSIS FOR RESOURCES MANAGEMENT OF PELAGIC FISH IN SIBOLGA WATERS

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ABSTRACT
Pelagic fish resources are resources that are limited in nature and can be recovered (renewable). Any reduction caused by death or arrest will be able to restore these resources to their original levels of productivity. Pelagic fish fishery resources in Sibolga Waters are included in fisheries management area 572 which has enormous potential and is directly facing the Indian Ocean. This study aims to analyze the bioeconomics, utilization rate, and efforts to manage pelagic fish resources using the Gordon scahefer method in Sibolga Waters, Central Tapanuli. The utilization rate of pelagic fish Sibolga Waters has experienced overfishing in 2018 of 103%, in 2019 which was 109% and 102% in 2019. The next management efforts that can be carried out based on bioeconomic analysis are a reduction in the level of effort by 1,894 trips and a reduction in the number of catches by 1,740 tons so that aquatic resources are sustainable again. This can be done with the restriction of the capture fleet. Based on the results of bioeconomic analysis, management efforts should be carried out in accordance with MEY conditions where the most optimal catches and profits are obtained.

KEY WORDS
Business, fish resources, Sibolga waters.

Sibolga waters are the largest producer of pelagic fish resources directly facing the Indian Ocean in North Sumatra Province. Some of the main commodities produced in Sibolga waters such as kitefish, bloating, tembung, selar and anchovies are limited in nature and can be recovered (renewable), where any reduction caused by death or fishing will be able to restore these resources to their original level of productivity. The production of pelagic fish resources in Sibolga waters has fluctuated over the past five years. The production of small pelagic fish resources in 2017 increased to 2019 from 7,236 tons to 9,528 tons but there was a decrease in production in 2020 to 8,898 tons and in 2021 it was 7,855 tons (North Sumatra Fisheries Service, 2021). The production of pelagic fish resources in Sibolga waters has fluctuated over the past five years. The production of small pelagic fish resources in 2017 increased to 2019 from 7,236 tons to 9,528 tons but there was a decrease in production in 2020 to 8,898 tons and in 2021 it was 7,855 tons (North Sumatra Fisheries Service, 2021). Factors causing fluctuations in the potential resources of pelagic fish can be assumed to be caused by environmental changes and improper effort arrangements, this is in line with the opinion of Muniarti (2011) that environmental changes can also affect fish abundance. Muawanah, et al., (2014) that the increasing number of fishing trips can increase catches however, if not supported by proper oceanographic conditions or fishing grounds then catches may decrease.

Sibolga waters are included in the 572 marine fisheries management area in Sibolga City, Central Tapanuli has enormous potential because it is directly facing the Indian Ocean. Pelagic fish resources are a superior commodity produced in the waters of Sibolga, Central Tapanuli. Fish production in 2017 of 7,236 tons increased to 2019 and 9,003 and 9,528 and decreased again in 2020 and 2021 to 8,898 and 7,855 tons. The utilization rate of kitefish in Sibolga Waters is suspected to be close to the limit value of the maximum value of sustainable Yield (MSY) and Maximum Economic Yield (MEY). Fishing for fish resources in Sibolga waters, which is still open access (open to every fisherman), is feared to cause overfishing. The high need for kitefish can further increase the exploitation of these fish resources. As a result, there will be a decline in population growth that continues with extinction (Sugiyono, et al., 2015). Fisheries management, in addition to providing benefits, also leaves various problems, such as overfishing and habitat destruction.

Fisheries management, in addition to providing benefits, also leaves various problems, such as overfishing and habitat destruction (Cahyani, 2013). This will obviously affect the sustainable potential and sustainable economic results in Sibolga Waters, based on this, it is necessary to have a stock assessment research as a solution to the problems that occur (Rahman, 2013). Any scientific study of fisheries is to determine the productivity of a fishery resource, the effect of fishing on resources as well as the impact of changes in fishing patterns This will obviously affect the biological and economic sustainability potential of pelagic fish resources in Sibolga waters, Based on this, it is necessary to have studies to obtain data and information related to the potential and condition of small pelagic fish fishery resources to produce optimal and sustainable management efforts and ensure the sustainability of pelagic fish resources. Information and data related to the condition and potential resources of pelagic fish can be the basis for research on analyzing the bioeconomics of small pelagic fish found in Sibolga Waters.

METHODS OF RESEARCH

The research has been conducted from January to February 2021, where secondary data was collected from the Marine and Fisheries Service, District Office, local TPI and BPS and VAT Sibolga Sibolga City, Central Tapanuli. A map of the location where the secondary data was taken can be seen in Figure 1.

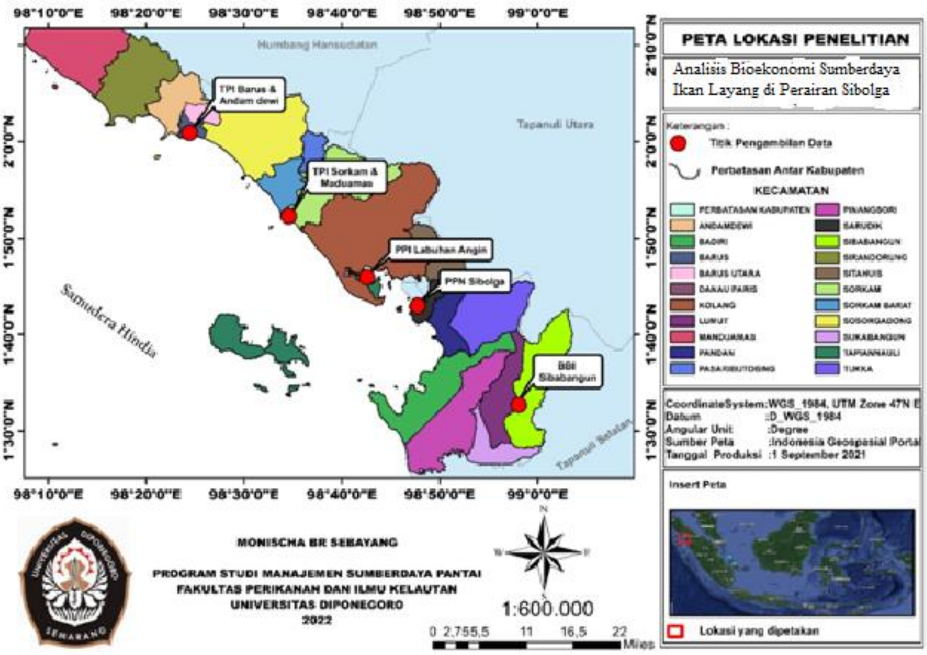

Figure 1 – Map of Research Secondary Data Collection Location

The tools and materials used in this study include questionnaires for direct interviews with Sibolga Water Fishermen and Statistical Software to process statistical data, Microsoft Excel for processing data and Capture Fisheries Statistics Data Series as processed data.

The data taken in this study are primary data and secondary data. The primary data of dambil directly to the field using questionnaires and secondary-data were obtained from the Sibolga Fisheries and Marine Service, the Nusantara Sibolga Fishing Port and the Central Statistics Agency (BPS) of Sibolga City. Primary data and secondary data taken in the study are presented in Table 1.

Table 1 – Primary Data taken in the study

No.	Data Description	Data source
1	Jenis Alat Types of fishing gear	Interview with Sibolga fishermen
2.	Fishermen's Fishing Equipment Production	Interview with Sibolga fishermen
3.	Ship capacity	Interview with Sibolga fishermen
4.	Production per trip capture	Interview with Sibolga fishermen
5.	Fish Production Price	Interview with Sibolga fishermen

Fish Catch Analysis The analysis of data used to determine the number of catches per attempt (CPUE) of the maximum fish catch in simple terms according to Schaefer (1957) proposed by (Noija 2014) CPUE has the formula:

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

Where: CPUE = Number of catches per unit of capture attempt to I; Catch = catch to I; Effort = attempted capture to i.

The formula used to standardize the arrest attempt is as follows:

$$\text{FPI} = \frac{\text{CPUEi}}{\text{CPUEs}}$$

Where: FPI = Fishing Power Index; CPUEi = CPUE of the fishing gear to be standardized (tons per unit /trip); CPUEs = CPUE standard fishing gear (tons per unit/trip).

The formula used for standardization efforts is as follows:

$$\text{fs} = \text{FPI x fi}$$

Where: fs = Attempted capture of standardization results (unit/trip); FPI = Fishing Power Index; Fi = Capture attempt to be standardized (unit/trip).

The schaefer method (Sparre and Veneme, 1999 in Noija, 2014), as follows:

$$\text{MSY} = -\frac{a^2}{4b} \qquad F_{Opt} = -\frac{a}{2b}$$

Where: a - Intersept value, b - Slope value.

MEY occurs when the profit is at the breaking point, provided that the first derivative of the profit against E is equal to 0 (first order condition or FOC) and the second derivative C against E is negatively valued (second order condition or SOC). Here's the first derivative of the gain against E equal to zero:

$$TR = p(\alpha E - \beta E2) \qquad (1)$$
$$TC = c.E \qquad (2)$$
$$\frac{d\pi}{dE} = \frac{dTR}{dE} - \frac{dTC}{dE} = 0 \qquad (3)$$
$$p\alpha - 2p\beta E - c = 0 \qquad (4)$$
$$p\alpha - c = 2p\beta E \qquad (5)$$

Then the EMEY and CMEY formulas are as follows:

$$EMEY = p\alpha - c / 2p\beta \qquad (6)$$
$$CMEY = \alpha(EMEY) - \beta(EMEY)2 \qquad (7)$$

Where: c = cost per trapping attempt (Rp), p = fish price (price) (Rp), C = number of production (kg), E = attempted capture (trip), TR = total receipts (Rp), TC = total expenses (Rp), π = profit.

A statistical bioeconomic analysis based on the Gordon-Schaefer model, developed by Schaefer using the logistics growth function developed by Gordon. The logistics growth function model is combined with economic principles, namely by including the price factor per unit of capture and cost per unit of effort in the equation of its function. There are three equilibrium conditions in the Gordon-Schaefer model, namely, MSY (Maximum Sustainable Yield), MEY (Maximum Economic Yield), and OAE (Open Access Equilibrium). Statistical Bioeconomic analysis based on the Gordon-Schaefer model can be carried out by the linear regression method.

Table 3 – Gordon-Schaefer Static Bioeconomic Formula

	MSY	MEY	OAE
C (kg/ton)	$\alpha^2/4\beta$	$\alpha EMEY - \beta(EMEY)^2$	$\alpha EOAE - \beta(EOAE)^2$
E (trip/tahun)	$\alpha/2\beta$	$(p\alpha - c)/(2p\beta)$	$(p\alpha - c)/(p\beta)$
TR (Rp/tahun)	C_{MSY} x P	CMEYx P	COAE x P
TC (Rp/tahun)	c x E_{MSY}	c x EMEY	c x EOAE
π (Rp/tahun)	$TR_{MSY} - TC_{MSY}$	TRMEY - TCMEY	TROAE – TCOAE

Source: Wijayanto, 2008; Rachman 2013.
Note: c = cost per attempted capture (Rp/unit/year); p = fish price (price) (Rp/kg); C = number of production (kg); E = capture attempt (unit); TR = total receipts (Rp); TC = total expenses (Rp); π = profit.

Utilization rate is fish resources that have been utilized calculated per year. The percentage value of fish resources that have been utilized can be known by the following formula.

$$T = \frac{Ci}{TAC} \times 100\ \%$$

Where: Ci = Catch of the i-year, TAC = Total Allowable Catch (80% of MSY value), T = Utilization Rate.

RESULTS AND DISCUSSION

Pelagic Fish Resource Production in Sibolga Waters. Data on the amount of production of pelagic fish resources using purse seine fishing gear in 2017-2021 can be seen in Figure 2. The production of kite fish catches from purse seine fishing gear in Sibolga Waters in 2017 totaled 7,236 tons of catches, then increased in 2018 with a total catch of 9,003 and 2019 with 9,528 tons, then decreased again in 2020 (8,898 tons) and 2021 7,855 tons close to the value of MSY and MEY and it is predicted that if left unchecked, it will experience overfishing in the following years.

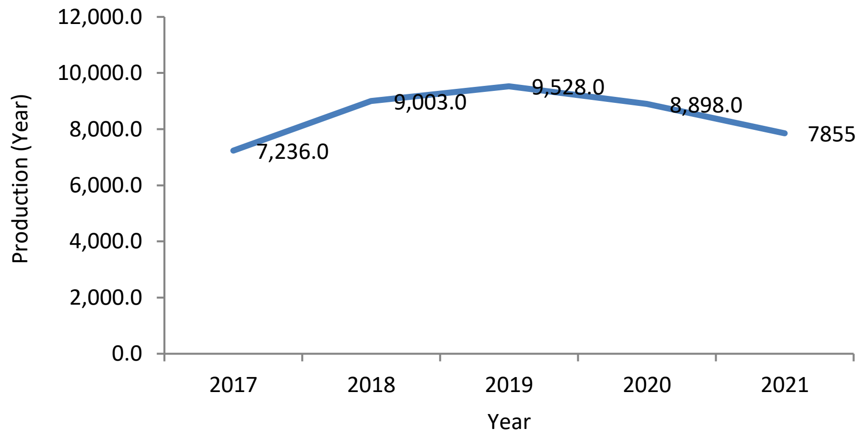

Figure 2 – Pelagic Fish Resource Production

It is suspected that the number of stocks or the presence of small pelagic fish resources that are already small and have experienced overfishing in the Sibolga Waters, The production of kite fish resources has experienced fluctuations due to various factors that influence each other in capture fisheries activities. This is in accordance with the opinion of lorenza opinion, (2020) that fluctuations in catches are influenced by the presence of fish, the number of fishing attempts, and the success rate of fishing operations.

Relationship trip and CPUE Fish Resources Pelagic Fish. Based on the results of research data analysis, the relationship between CPUE and kite fishing efforts (2017-2021) can be seen in. The relationship of CPUE to effort produces the approximate values of the intercept (a) and slope (b) parameters through linear regression. The relationship between the capture attempt and the CPUE of the small pelagic fish suggests that an increase in the capture attempt will lead to an increase in the CPUE with the regression equation Y= -1E -04x + 1.837 The effect of the capture attempt on the standard CPUE is obtained by regressing the capture attempt value and the standard CPUE.

The relationships of CPUE to effort results in the alleged values of intercept parameters (a) and slope (b) through linear regression. The relationship between the fishing attempt and the CPUE of the small pelagic fish suggests that an increase in the capture effort will lead to an increase in the CPUE with the regression equation Y= -1E-04x + 1.837 which means that if an increase in the capture attempt is made one trip, it will reduce the CPUE by 0.00004 tons per trip. Based on the equation obtained the value of a = 0, and b = -0.00002, the resulting value of a is positive and b is negative. This is in accordance with the opinion of Sparre and Venema (1999), stating that the slope of b must be negative when the catch per unit of effort decreases for each increase (effort). The value of R^2 = 0.596, meaning that 59.6% of the decrease in catch production (y) was caused by capture efforts (x) while by 40.4% the decrease in catch production (y) was caused by natural and biological factors (Kurniawan, et., al 2019), the resulting value of a is positive and b is negative. This is in accordance with the opinion of Sparre and Venema (1999), stating that the slope of b must be negative when the catch per unit of effort decreases for each increase (effort). The relationship between CPUE and fish resource effort results in a downward trendline which means an excess of fishing efforts, This is in accordance with the opinion of Cahyani (Kurniawan, et.al 2019) said that the declining CPUE trend is an illustration that the level of exploitation of fish resources cannot produce catches even though fishing efforts are increased. Sobari (2018) added the statement that the higher the effort, the CPUE value shows symptoms of decline.

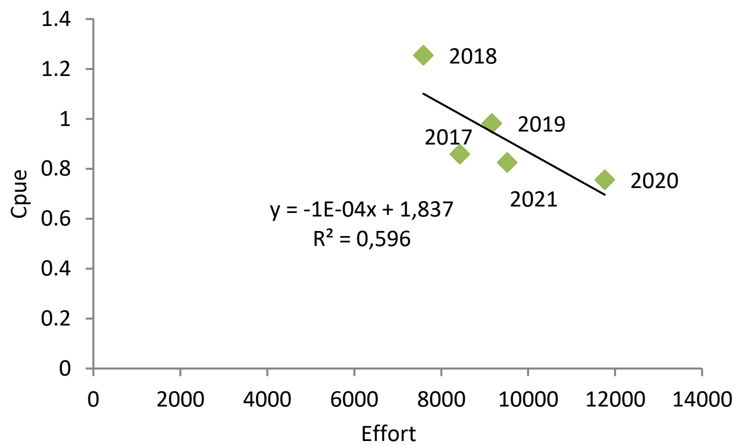

Figure 3 – Relationship between CPUE and Trip Standart Pelagic Fish

The utilization rate of small pelagic fish at the Nusantara Sibolga Fishing Port can be known through the comparison of the value of the first year's fish catch with MSY. The results of the calculation of the utilization rate are contained in Table 3.

Table 3 – Utilization rate of peagic fish landed in Sibolga Waters

Year	Ci (ton)	MSY (Tons/Years)	%
2017	7.236	8.697	83
2018	9.003	8.697	103
2019	9.528	8.697	109
2020	8.898	8.697	102
2021	7.855	8.697	90

Table 3 shows that the production of pelagic fish resources from 2017-2021 is above the TAC value and there has even been overfishing in 2018, 2019,2020. This shows the need for small pelagic fish resource management to overcome problems that can damage habitat diversity that causes overfishung. This is influenced by the catch per unit of capture effort (CPUE) which reflects the comparison between the catch and the higher CPUE value reflecting a better level of effort use efficiency. CPUE values from 2017 to 2021 fluctuated tend to increase. This happened because during the period of the year there was an increase and decrease in the number of arrest attempts (efforts). This is as per Khaerunnisa (2015), (Mardhan 2019) which states that, CPUE is inversely proportional to the attempted capture. The higher the capture attempt, the lower the CPUE value. The more arrest efforts, the more it will reduce the catch. This is due to the increased competition between operating fishing gear and limited resource capacity. Purse seine fishing gear or known as ring trawling is a fishing gear that is generally used by fishermen to catch small pelagic fish. Schooling fish is a way for purse seine vessels to operate fishing gear. The average ship fleet owner has only one purse seine. The ring trawl has good prospects in the future because it absorbs quite a lot of labor. In addition, this fishing gear has high efficiency in the use of capital and can generate large income (Tarukay, 2018).

Analysis of Maximum Sustainable Potential (MSY) of Pelagic Fish. Small pelagic fish resources are the main catch targets of Purse Seine fishing gear in the Sibolga waters of North Sumatra. The MSY calculation of the Schaefer model is used to determine the availability of potential floating fish resources in the waters of Sibolga North Sumatra.

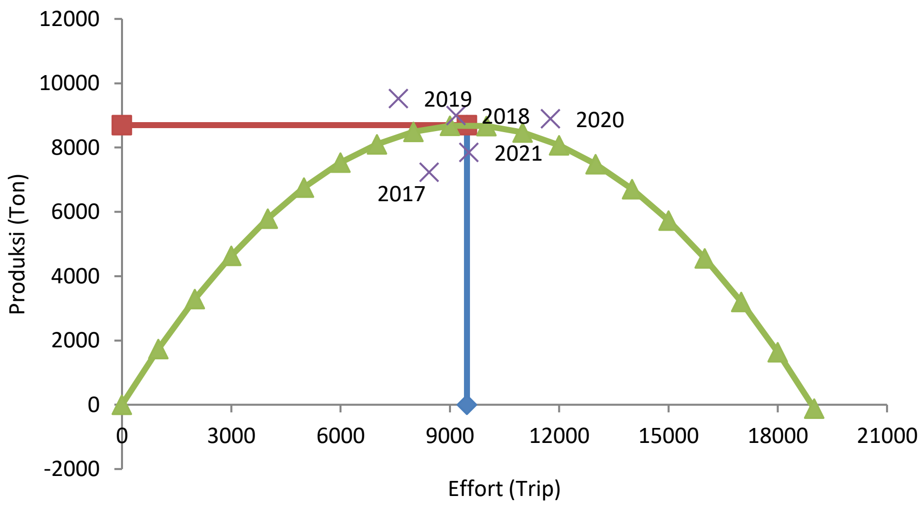

Figure 4 – Maximum Sustainable Yield of Pelagic Fish

Figure 4, shows that the CMSY value of small pelagic fish is 8,697 tons/year and EMSY is 9,469 trips/year. The results of the estimation of the Schaefer model, indicate that the potential for small pelagic fish in 2017 and 2021 has not exceeded the limits of CMSY or EMSY. However, in 2018 and 2019 and 2021 pelagic fish production has exceeded the maximum CMSY limit or overfished. This is influenced by arrest efforts in 2020 and 2021 above the EMSY value. The increase in fishing efforts without proper regulation will lead to a decrease in the production of small pelagic fish resources, this is in accordance with the opinion of noordiningroom, et., al 2015 that there is a need for a policy in utilizing the availability of pelagic fish stocks, so as not to cause stock drainage in the following year. According to Mayu, (2018) stated that the draining of stocks due to excess effort will threaten the water resources of the fishing grounds and can result in a decrease in the welfare of the fishermen themselves.

Bioeconomic analysis of standard purse seine fishing gear. Based on the results of calculations with the Gordon Schaefer bioeconomic model by purse seine fishing gear from 2017 to 2021, the results of MSY, MEY and OAE values on pelagic fish resources in Sibolga Waters can be seen in Figure 5.

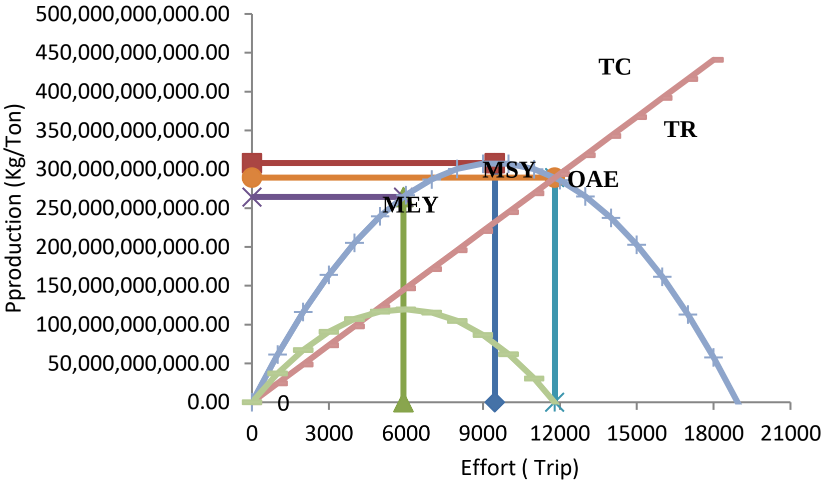

Figure 5 – MSY, MEY and OAE Curves of Pelagic Fish Resources in Sibolga Waters

Bioeconomic analysis is carried out in various fisheries management regimes, namely MSY, MEY and open access (OA) fisheries. Bioeconomic analysis is carried out in determining the value of efforts, production and economic rents from each management regime. The results of the bioeconomic analysis are presented in Table 10. Figure 6 shows a very high effort in actual conditions compared to sole owner management conditions or maximum economic yields and maximum sustainable yield (MSY) management conditions, so this condition will cause improper resource allocation. According to Utami, et al., (2018), fisheries resources under MEY management conditions can provide information such as minimizing fishing costs, so that output prices become more competitive Maximum Economic Yield (MEY) takes into account the value of the catch and the cost of capture. Fisheries are said to be underfishing in the economic sense that it needs further development. If the fishery is said to be overfishing, if the actual catch does not reach the Maximum Economic Yield (MEY) due to excessive fishing efforts. If the policy objective is for economic benefit, then the optimum exploitation rate is set to achieve MEY, namely a continuous maximum income surplus (Total Sustainable Revenues) that exceeds fishing costs (Wijayanto,2016).

Maximum production at the MEY level is achieved before the optimal level of production at MSY conditions. According to Wiyono (2011), the use of fishing units in accordance with fish resources has developed various types of fishing technology, both traditional and modern. In addition, the increase or decrease in arrest efforts is suspected to be due to economic, seasonal and environmental factors. The level of effort required to achieve sole owner management conditions or maximum economic yield appears to be smaller than that required in achieving maximum sustainable yield (MSY) management conditions. Therefore, in accordance with the opinion of Susilo (2017) the balance of sole owner management conditions or maximum economic yield looks more conservative minded (more friendly to the environment) than the level of effort at the equilibrium point in the condition of managing maximum sustainable yield (MSY).

Table 4 – Results of bioeconomic analysis of pelagic fish resources

activity	C(ton)	E (Trip)	TR	TC	Profit
MSY	8.697	9.469	Rp. 308.051.689.624	Rp 231.951.341.640	Rp 76.100.437.984
MEY	7.464	5.904	Rp. 264.389.039.508	Rp 144.626.021.408	Rp 119.763.008.100
OAE	8.166	11.808	Rp 289.252.042.816	Rp 289.252.042.816	Rp -

The results of the bioeconomic model on conditions or activities of capturing maximum economic yield (MEY) obtained a catch of 7,464 tons / trip and the number of trips of capture of 5,904 trips / year will be obtained income receipts or TR (total receipts) of Rp. 264,389,039,508 with capital costs incurred or total costs (TC) of Rp. 144,626,021,408 rupiah so that profits are obtained with economic rents of Rp. 84,738,380,161 rupiah and bioeconomic results on activities maximum sustainable yield (MSY) obtained catches of 8,697 tons / trip with a fishing trip of 9,469 trips / year TR (total receipts) of Rp 308,051,689,624 rupiah with capital costs incurred or total costs (TC) of Rp 231,951,341,640 will be obtained from revenue Utilization of pelagic fish resources in several management models as follows:

1) The condition of sole owner or MEY obtained production (h) obtained by 8,697 tons per year, the level of effort (effort) carried out was 9,469 trips per year, and the economic rent (π) obtained was Rp 76,100,437,984 per year;
2) The condition of OAE has a production of 8,166 tons per year, efforts made as much as 11,808 trips per year and economic rent (π) obtained as much as Rp 0.00 million per year;
3) MSY conditions obtained production (h) of 8697 tons per year, effort of 9469 trips per year and economic rent (π) of Rp 76,100,437,984 per year.

Figure 6 shows that economic production and rents in actual conditions are lower than sole owner or MEY management conditions and MSY management conditions. This shows a comparison of the utilization of pelagic fish resources. The level of production, effort, and economic rent from the actual condition is shown to be smaller than that of mey and MSY. In MEY conditions, the level of effort is lower than that of MSY, but the economic rent obtained is greater than the MSY condition. Therefore, the balance of management conditions.

MEY is better compared to the level of effort at the equilibrium point on MSY conditions. This is in accordance with the opinion of Piliana, et.,al, (2015), that the fishing business at the MEY point provides maximum economic benefits both to the ship owner and to the crew, depending on the profit-sharing system used. Similarly, Dichmont et al (2010) state that MEY is a long-term equilibrium concept that refers to the level of output and the appropriate level of effort that maximizes the economic rent of fisheries activities. Meanwhile, according to FAO (2006) MSY management is the highest balance of catches that can continue to be utilized without exceeding the value of existing stocks. In addition, Larkin et al (2011) stated that MEY management is a sustainable economic solution by generating maximum economy, while MSY management is an alternative biological solution that maximizes catches sustainably. or TR (total receipts) of Rp 201,295,583,753 rupiah with capital costs incurred or total costs (TC) of Rp 141,382,734,6540 rupiah so that a profit of Rp. 183,463,353,052 rupiah was obtained while in conditions or open access activities a catch of 5,180 tons / trip with the number of arrest trips as much as 7490 trips / year where the total receipt (TR) obtained was Rp. 183,463,353,052 rupiah and the total cost the issued (TC) is equal to the total receipts of Rp 183,463,353,052 rupiah so that the profit obtained in open access activities is Rp 0 rupiah or not profit and not loss.

Recommendations in the management of pelagic fish resources in Sibolga Waters, seen from the calculation value of the bioeconomic analysis, Gordon Schaefer suggests that pelagic fish resources in Sibolga waters have abundant resource potential but tend to fluctuate from 2017 to 2021, if this is allowed to continue, it will certainly threaten the existence of flyover fish fishery stocks in Sibolga Waters. Based on the principle of demand and supply, if fishery stocks are threatened and fishing for fish resources decreases, prices will soar beyond the limit, the number of fishermen who catch pelagic and demersal fish resources continues to grow and fish resources will reach a critical point.

The results of the SWOT diagram analysis show that the priority of a suitable strategy in bioeconomic analysis in the management of kitefish resources is the WO (Weakness-Opportunity) Strategy. A strategy that considers weaknesses and opportunities so that development is in accordance with internal capabilities (Rangkuti, 2017). The ideal fisheries management policies applied to the management of elevated resources in Sibolga Waters:

1. Optimizing export demand for Kite Fish resources by collaborating with the Central Government to facilitate access to subsidized fuel for fishermen by utilizing the minopolitan Sibolga water area;
2. Development of knowledge and application of modern technology to fishing gear, fishing fleets so as to maximize the number of catches in meeting the demand for superior commodity needs;
3. Conduct socialization and training by cooperating with the central government by utilizing a large enough marketing network to be able to build and develop waste management infrastructure.

CONCLUSION AND SUGGESTIONS

Based on the results of the analysis of statistical data on capture fisheries in the waters of Sibolga City, the following conclusions can be drawn:

1. The actual and optimal utilization rate of small pelagic fish fisheries in Sibolga Waters in 2017-2021 has exceeded the TAC value and even overfishing in 2018-2020 has reached 103%, 109% and 102%, meaning that it exceeds the allowable fishing limit and effort in 2020-2021 exceeds the optimum effort value. The optimal utilization rate of kitefish in the waters is not to exceed MSY of 8,697 tons / year and should be in accordance with the number of can catches (TAC) of 6,957 tons / year to maintain the stability of kitefish stocks in natural waters;
2. The results of the analysis of the utilization of small pelagic resources are known that the balance of sole owner management conditions or maximum economic yield (MEY) looks more conservative minded (more friendly to the environment) than the management of open access (OA) and maximum sustainable yield (MSY);
3. The results of the SWOT diagram analysis show that the priority of a suitable strategy in bioeconomic analysis in the management of small pelagic resources is the WO (Weakness-Opportunity) Strategy. A strategy that takes into account weaknesses and opportunities so that development corresponds to internal capabilities.

Suggestions that can be submitted are:

1. Further research on the potential of kitefish resources in North Sumatra Province to obtain comparison results (MSY), MEY, OAE and (F opt) in sustainable fish resource management;
2. It is necessary to carry out a sustainable kitefish resource management system in the Elevated Waters in accordance with the territory of Indonesia based on the rules of FAO rules international countries that have succeeded in maintaining fishery stocks.

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