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Level of Utilization of Cakalang Fisheries with Pole and Line Catching Equipment in Kupang

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Abstract---*The purpose of this study was to estimate the maximum effort and maximum production value of skipjack tuna in Kupang. The data used in this study is primary data, especially about fish resources obtained through direct observation at the research site and interviews with fishery actors (fishermen/ABK, ship owners, collectors, TPI officers, and other stakeholders), and options using a list of questions/ structured questionnaire according to research objectives. Secondary data collected through fishery statistics reports include household fishery statistics (RTP), fleet and fishing gear statistics, production data from the Department of Fisheries and Marine Affairs of the Province of East Nusa Tenggara, the Department of Fisheries and Marine Affairs of Kupang City, PPP Oeba and PPI Tenau. This study describes the bioeconomic analysis of the utilization of mackerel fish resources in various regimes through the Gordon Schaefer Model with an estimation model of biological parameters. Data analysis was carried out using the resource stock abundance index through recording data on catches and the number of trips/boats/fishing gear in a time series, to determine the allocation of fishing effort to the abundance of fish. Furthermore, the calculation of the catch per effort (CPUE, Catch per Unit of Effort). Analysis of fishing effort allocation is carried out using economic profit forecasts with Revenue Per Unit Effort (RPUEj) analysis. The results showed that the average catch per unit of effort (2014-2018) was 3.31 tons/trip. The maximum sustainable effort (EMSY) is 705 trips/year with a maximum sustainable production value (hMSY) of 2404.90 tons/year. The price of skipjack tuna in Kupang is relatively low with an average of IDR 11.000,-/kg. This study also obtained an estimate of MEY Effort (EMEY) of 611 trips/year with a production (hMEY) of 2361.83 tons/year. While the actual fishing effort is 931 trips/year with a production of 2697 tons/year. Utilization activities show more biological and economic fishing efforts. For skipjack catching activities in Kupang with pole and line, it is recommended that the total allowable catch (TAC) is 80% of the MSY value.*
Keywords---cakalang fisheries, CPUE, MEY, MSY, sustainability.

Introduction

Optimizing fishery resources is closely related to the status of these fishery resources, the level of effort, and the number of catches allowed. In other words, knowing the status of pelagic fishery resources in each territorial water will be able to determine whether or not it is necessary to limit the level of effort in that water area. Another impact of knowing the status of fishery resources in the production of the allowed number of catches for these fish resources in each water area. In general, optimization in fishery resources will provide benefits to avoid overfishing in each water area. According to Mayalibit et al. (2014), more fishing conditions occur when fishing activities catch a lot of fish individuals that are too young. So there is no chance for them to reach adult size. Meanwhile, the occurrence of catching is more rejuvenation when fishing activities catch a lot of individuals who are ready to spawn (spawning

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stock), so the opportunity to produce young fish individuals is reduced (threatened). Therefore, proper management of fisheries resources is needed to be sustainable.

In general, skipjack tuna is one of the pelagic fishery resources that are widely used as objects in the capture fisheries business, both in Indonesia and in other countries. Every year, there is an increase in the fishing fleet and production of skipjack tuna in Indonesia. Economically, skipjack makes a major contribution, which is indicated by the majority of coastal communities having jobs as fishermen, both in catching, processing, trading, and supporting industries (Rochman et al., 2015). Skipjack tuna is also listed as an export commodity in the form of fresh, frozen, or processed. From these export activities, the Indonesian state received additional foreign exchange which was important for the balance of the foreign trade balance. Foreign exchange entering the local government will lead to an increase in the welfare of the population (Saputra et al., 2016).

The decrease in the amount of production of fish resources will affect the decrease in the economic value obtained. The utilization of fishery resources must be based on socio-economic aspects as well as fish biology, sustainability, and environmental conditions to support sustainable use activities (Fauzi & Anna, 2005; Pope et al., 2004). One approach that is often used in solving these problems is the bioeconomic approach. The bioeconomic approach used in this study is the Gordon Schaefer Model. This approach describes the value of utilization and management in the regime of maximum sustainable potential (MSY), maximum economic potential (MEY), and open fisheries (OA) with estimated values of biological parameters.

Methods

This research was conducted in Kupang in 2019 with sampling locations in PPP Oeba and PPI Tenau. The method used is the survey method through quantitative and descriptive analysis. Primary data were obtained directly from sampling fishermen in the field and the related UPTD including fishing costs per trip, catch per trip, length of trip, and the number of trips per year, while the secondary data needed was obtained from the Department of Fisheries and Marine Affairs of Kupang covering production data of Cakalang and Cakalang fish. Time Series fishing effort (2014-2018) and skipjack tuna price (2014-2018).

Data analysis
Determining Utilization Rate

Determine the optimum fishing effort (F_{opt}) and MSY can be calculated using the Schaefer equation. Optimum effort (F_{opt}) and Maximum Sustainable Yield (MSY) are calculated using the following equation:

$$F_{opt} = \frac{a}{2b} \quad \text{....(1)}$$

$$MSY = \frac{a^2}{4b} \quad \text{....(2)}$$

Information:
α is the intercept and b is the slope of the linear regression equation

The Schaefer equation is often used to calculate MSY and optimum fishing effort (Fopt) because calculations using the Schaefer equation are simple, easy and the results are accurate and easy to understand by anyone, including policymakers (Ghofar, 2005). The utilization rate of fish resources is calculated by the following formula:

$$\text{Utilization rate} = \frac{Ci}{MSY} x100\% \quad \text{....(3)}$$

Information
Ci = Number of current catches; MSY = Maximum Sustainable Yield
In using this method some basic assumptions must be considered are:

1) Fish stock is considered as a single unit and is not guided by its population structure at all.
2) Fish stocks are always in a state that tends to a steady-state situation according to biomass growth models such as logistics curves.
3) The catch and fishing efforts are random data.
4) The catch landed comes from the waters of the Savu Sea and no catch is landed outside the area.
5) There is no significant change in the capture technology.

Dwiponggo (1987) and Bintoro (2005), classify the level of utilization of fish resources into 6 (six) groups, namely (1) exploited if fish resources are only used; (2) lightly exploited (if the utilization rate of fish resources is below 25% of their sustainable potential); (3) moderately exploited (if the level of utilization of fish resources is below the allowable catch); (4) fully exploited (if the level of utilization of fish resources is the same as their sustainable potential); (5) overexploited (if the level of utilization of fish resources has exceeded its sustainable potential); and (6) depleted (if the utilization rate of fish resources continues to decline close to extinction).

Bioeconomic analysis

After the biological parameters are known, then they are included in the estimation of economic parameters by Gordon Schaefer (Nurhayati, 2013), in the assumption that fish production and prices are assumed to be constant (unchanged). The fishing cost used is the average of the fishing operational costs which include the cost of fuel, oil, food, and user fees. According to Fauzi (2004), the average fishing cost can be calculated using the formula:

$$C = \frac{\Sigma ci}{n} \quad \ldots\ldots (4)$$

c is the average fishing fee (rupiah/trip), ci is the nominal fishing fee of the ith respondent, and n is the number of respondents. The price of skipjack tuna is also determined based on the average skipjack tuna price with the formula (Fauzi, 2004):

$$p = \frac{\Sigma Pi}{n} \quad \ldots\ldots (5)$$

p is the average fish price (rupiah per kg), pi is the nominal price of skipjack tuna per fisherman, and n is the number of respondents. If the two economic parameters are known, then TR (Total Revenue), TC (Total Cost), then the economic benefits are obtained by the equation (Fauzi, 2004):

$$TR = ph$$
$$TC = cE$$
$$\pi = TR\text{-}TC \quad \ldots\ldots (6)$$

The calculation of the maximum sustainable value of MEY according to Schaefer is formulated as follows:

$$f_{MEY} = \frac{ap-c}{2pb} \quad \ldots\ldots (7)$$
$$Q_{MEY} = MEY = a(f_{MEY})\text{-}b(f_{MEY})^2 \quad \ldots\ldots (8)$$

The economic parameters needed in the bioeconomic analysis are the real price per tonne and the operational cost per trip of the skipjack fishing vessel. Price values and operational costs obtained from field surveys and secondary data are converted into real values using the Consumer Price Index (CPI). This is intended to minimize the effect of inflation on the price value and operating costs. The cost of catching fishing effort includes fixed costs (fixed costs) and variable costs (variable costs). Fixed costs include ship depreciation, fishing gear depreciation, machinery depreciation, and others. Variable costs are the cost of fuel (diesel), preservatives (ice and salt), oil, and food (Zulbainarni, 2019).

Results

Skipjack resource analysis
Estimating sustainable production and optimal effort

Estimation of optimal production and effort based on Maximum Sustainable Yield (MSY) was carried out in this study. This is done to find out how much sustainable production and optimal effort are allowed for skipjack tuna fisheries in Kupang so that skipjack catching activities can last for a long time and provide maximum profit but the sustainability of skipjack tuna is maintained (Tuli et al., 2015; Fiala, 2008). The table below shows the results of the calculation of the optimal production and effort along with the actual production and effort in Kupang.

Table 1
Value of sustainable production and optimal effort as well as actual production and effort in Kupang

	Maximum Sustainable Yield (MSY)	Actual
Production (tons/year)	2.209,42	2.697,87
Effort (trips/year)	719	931

In Table 1. it can be seen that the sustainable production of skipjack tuna based on MSY is 2,209.42 tons/year. The sustainable production is greater than the actual production produced by skipjack fishermen in Kupang, which is 2,697.87 tons/year. This is inversely proportional to the effort made by the skipjack fisherman where the actual effort is greater than the optimal effort based on MSY. This means that skipjack fishing activities have experienced great fishing pressure (Sareng et al., 2020). The actual effort is 931 trips/year and the optimal effort is 719 trips/year.

It can be seen in Figure 1. that the actual production and effort of skipjack fishery activities in Kupang is on the right side of the MSY curve or exceeding the MSY limit. On the MSY curve, information is obtained that skipjack tuna production in Kupang has decreased or is smaller than its sustainable production because the actual effort of skipjack catching activities in Kupang far exceeds its optimal effort. This is very worrying because if the effort in skipjack fishing activities in Kupang continues to be increased, the production of skipjack tuna in Kupang will continue to decline and even cause the extinction of skipjack tuna resources in Kupang.

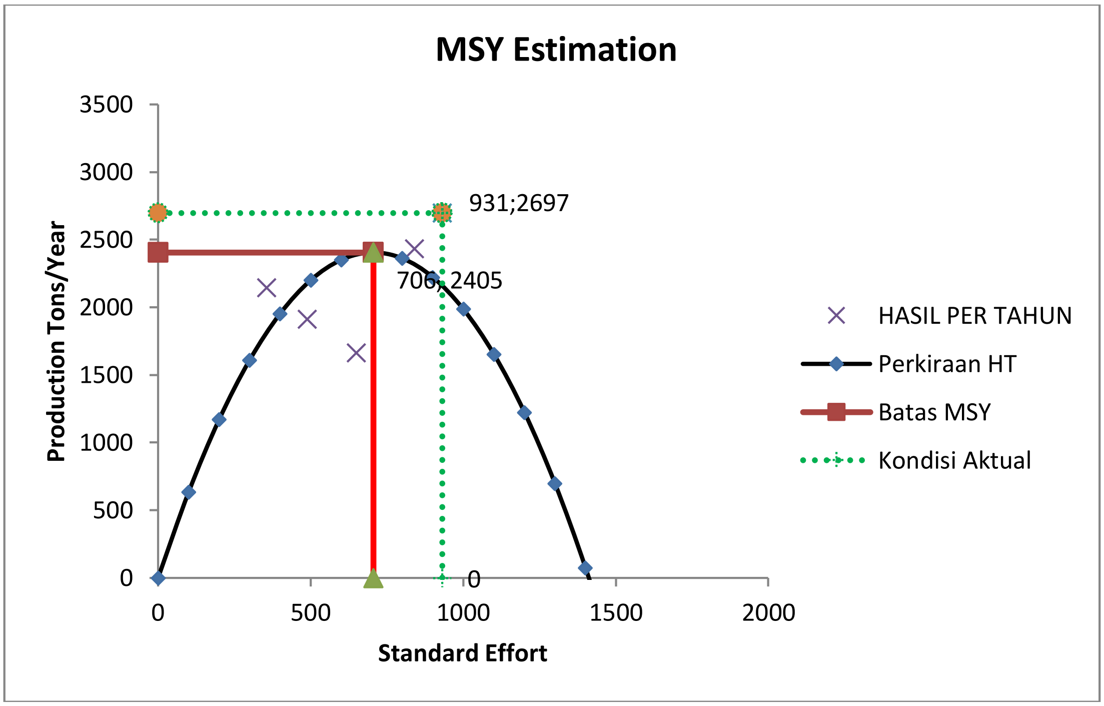

Figure 1. MSY curve for skipjack tuna fisheries in Kupang

Economic parameter estimation

Based on the survey results, it is known that in the first marketing channel, skipjack tuna was purchased by agents from fishermen for IDR 10,000-Rp 12,000/kg. In Kupang, fish are not grouped by size. Although the price is lower than the retail selling price in the market, this is still chosen by Pole and Line fishermen because there has been a partnership between the shipowner and the agent so that all catch must be sold to the agent (Sri, 2013). Fishermen are only tasked with catching fish, they have no authority in marketing. So, in this case, the owner chooses to partner with an agent because it is considered more efficient, that is, all catches are directly purchased by the agent, even though the price is lower than the retail price in the market because the owner no longer needs to incur transportation costs. In addition, sometimes agents also assist owners in terms of capital as part of a partnership.

The cost of fishing in fisheries (cost of fishing) is all costs incurred to buy production factors or effort including costs per trip (cost per trip) and total costs (fixed costs plus variable costs). Fishing costs are based on the assumption that only fishing factors are taken into account and are considered constant, so in this study fishing costs are defined as variable costs per trip and are considered constant. The costs involved in capture fisheries activities are reflected in the costs of catching, namely the cost of ice, salt, diesel, and food. Based on the results of the analysis, the average real price of skipjack tuna in the local market in the period 2014 - 2018 is IDR 11.000,- per kg.

Table 2
Cost structure of skipjack tuna (*Katsuwonus pelamis*)

No.	Cost	Specification	Price	Percentage
1	Catching tool	Fishing gear reserve	IDR 350.000	1,35%
2	Fuel	Solar 1.5 ton/trip	IDR15.075.000	58,15%
3	Supplies	Clean water and food	IDR3.400.000	13,11%
4	Live Bait	Buy on Chart	IDR 6.000.000	23,14%
5	Ice Cube	100 blocks	IDR 1.100.000	4,24%
Total			IDR 25.925.000	100%

Based on the results of interviews with 5 fishermen respondents, it can be seen that the average yield of the largest percentage is 58.15% on the diesel variable and the smallest percentage on the fishing gear reserve variable is 1.35%. The cost structure for skipjack fishing operations is carried out on each trip for 3-4 days at sea.

Table 3
Bioeconomic results of skipjack tuna *(Katsuwonus pelamis)*

Variable	Condition		
	MEY	MSY	Actual
Catch (tons)	2361,83	2404,90	2697,87
Effort (trip)	611,48	705,57	931
Total Income (IDR)	25.978.602.469	26.453.860.621	29.676.570.000
Total Expenditure (IDR)	15.122.250.000	17.448.750.000	23.753.568.231
Economic Profit (IDR)	10.856.352.469	9.005.110.621	5.923.001.769

Based on Table 3. it is known that the maximum catch of skipjack in the waters is indicated by the MSY value of 2404.90 tons with a maximum effort of 705 trips. In MEY conditions, the effort made was 611 trips lower and resulted in greater profits than MSY. The following is a bioeconomic model curve presented in Figure 2.

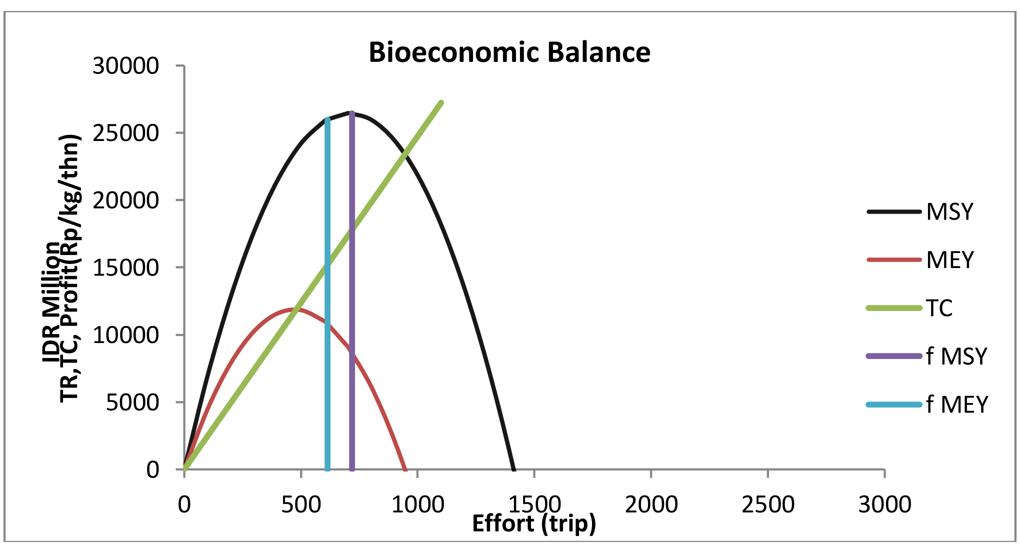

Figure 2. The curve of the bioeconomic model using the Schaefer model

Figure 2. shows that the effort in actual conditions has exceeded the MEY and MSY lines. This indicates that overfishing has occurred economically and biologically.

Discussion

PPI Tenau and PPP Oeba are located in East Nusa Tenggara, precisely in Kupang City. One of the catches is skipjack tuna. According to data up to 2018, this fish belongs to the dominant group of fish caught. The highest catch was in 2018, which was 2,697.87 tons and the lowest was in 2014 at 1,666.74 tons. The increase in production in 2014-2015 was due to a decrease in fishing effort from the previous year so that the catch per trip has increased. According to Nabunome (2007), that each fish species can reproduce that exceeds its production capacity (surplus), so that if this surplus is harvested (no more and no less), the fish stock will be able to survive sustainably, otherwise a decrease in production will occur. if the increase in fishing effort is carried out without regulations. This condition can affect the skipjack tuna population which will experience a decline.

The catch and effort to catch skipjack tuna has increased over the last 5 years with the highest catch in 2018, namely, 2697.87 tons. According to Setyadji & Amri (2017), the increase in catches in the east monsoon coincided with the occurrence of upwelling in the south of Java-Bali-Nusa Tenggara, allegedly related to an increase in the primary productivity of the waters followed by the availability of food (prey) for swordfish at that time. On the other hand, in the west monsoon when the effect of upwelling water masses ends, the availability of prey is thought to decrease followed by a decrease in the catch (low CPUE).

The correlation between CPUE and effort shows that the estimation parameter value for skipjack tuna obtained an intercept value (a) of 6.8169 and a slope (b) of -0.048, thus forming a linear equation of Schaefer CPUE = -0.0043x + 6.1424. The relationship between this equation can be interpreted that if the catch is x units per year, it will reduce the CPUE value by 0.0043 tons per year. This indicates that the productivity of fishing gear decreases when fishing effort increases (Zulbainarni, 2019).

Sustainable potential or better known as the surplus production model explains the sustainable and sustainable use of fish resources. This model regulates the allowable fishing effort to catch fish resources without exceeding the limit of sustainable catches. The analysis is estimated by using the surplus production model developed by Gordon - Schaefer. The data used for the analysis is annual catch data from 2014 to 2018. Based on Figure 2, from 2014 to 2018 the CPUE value was outside the balance of the surplus production model curve, indicating overfishing. Table 4. explains that the allowable catch is 1923.91 tons/year and the maximum sustainable potential is 2404.89 tons/year (Shono, 2008; Stephens & MacCall, 2004; Campbell, 2004).

The bioeconomic analysis aims at the maximum level of exploitation for fishery actors (Syarifuddin, 2014). Economic studies are also known as the MEY (Maximum Economic Yield) approach or economically sustainable catch while preserving fish resources and the environment. Another approach is MSY (Maximum sustainable yield) or maximum sustainable catch can be defined as the level of utilization of fishery resources without destroying the sustainability of resources (Mugo et al., 2010). Estimation of MEY calculation using the value of price (p) and cost (c) (Rindorf et al., 2017; Merino et al., 2015).

Table 3. shows the maximum catch in the waters, which is indicated by the MSY value of 2,404.89 tons with a maximum effort of 706 trips/year. In MEY conditions, the effort made was lower at 611 trips/year and the catch was lower at 2,361.83 tons but resulted in a higher profit than MSY. When viewed from the TAC (amount of allowable catch) the MSY condition is much higher (Guillen et al., 2013; Mesnil, 2012; Kempf et al., 2016). The fishing effort in actual conditions is greater than the MSY condition, so it can be said that skipjack tuna resources have been caught more biologically. Efforts in MEY conditions are lower than the actual conditions, so it can be said that skipjack tuna has been caught more economically. According to Widodo (2006), when the actual level of fishing effort exceeds the required level (under MSY and MEY conditions), the fish resource can be said to be overfishing both biologically and economically.

The recommended management is using the MEY regime, namely, reducing the number of trips by limiting the fishing effort to 611 trips. If the fishing effort is reduced in actual conditions (931 trips) and MEY conditions (611 trips), a value of 320 trips will be obtained. This is assumed to save the operating budget of IDR 8,296,000,000, - So the impact of increasing profits from IDR 5.923.001.769,- up to IDR 10,856.352,469,-.

Conclusion

The sustainable potential of skipjack tuna is 2404.89 tons/year. Skipjack tuna has experienced biological overfishing because the fishing effort in actual conditions is greater than MSY, the catch under MSY conditions is higher than the allowable catch and actual conditions. The MEY condition shows that skipjack tuna is experiencing economic overfishing because the actual condition has exceeded the MEY value. The suggested management of skipjack pole and line fisheries is a decrease in the fishing effort by 611 trips/year.

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