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Stock Study of Bali Sardinella Fisheries at Pengambengan Nusantara Fishing Port, Bali

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Abstract. Stock assessment is one of the efforts to see the impact and influence of fishing activities on fish stocks and populations. One of the fishery resources that has important economic value in Indonesia is Bali sardinella fisheries. The high production of Bali sardinella fisheries at the Pengambengan Nusantara Fishing Port (NFP) encourages an increase in intensity and catch effort, so it is feared that overexploitation may occur. This study uses primary data and secondary data from Pengambengan NFP, to analyze the level of effort, catch, and economic rent of Bali sardinella fisheries under MSY, MEY, and OA conditions. The result of the linear equation CPUE = -0.00008f + 3.1053, if the capture effort is increased it will reduce the CPUE value, and vice versa. The regression results of the Schaefer Model obtained EMSY results of 4,691 trips per year, MSY of 17,639 tons per year, and TAC of 14,111 tons per year. The results of the bioeconomic model prediction obtained EMEY and MEY values, namely 4,554 trips per year and 17,624 tons per year.

Keywords: Sardinella lemuru, MSY, MEY, OA, Indonesia.

1. Introduction

Stock is a group of organisms of a species that have the same characteristics and occupy a certain geographical area. A stock is a group of fish whose distribution at geographical boundaries can be determined or known. Likewise with fishery activities, fishing fleets that exploit groups of fish can be known. Stock must belong to the same race within the same species. A group or subgroup of fish of a species is said to be a stock if differences in the group or mixing with other groups can be ignored without making erroneous conclusions (Saputra, 2009). Stock assessment is needed as basic information in sustainable fisheries management (Setiyowati, 2016). Sustainable and sustainable fisheries can be achieved through good fisheries resource management efforts.

Stock study is one of the efforts to see the impact and influence of fishing activities on the stock and population of these fish. Some of the benefits and uses of stock studies include guessing decision-making from management options given due to uncertainty caused by incomplete data that leads to bias, changes in technology, fishing fleets, and fish behavior including interactions between the two (Sparre and Venema, 1992). This means that stock review is the first step that will determine the next management step, so information related to identifying '*unit stock*' of fish resources is needed.

One of the fishery resources that has important economic value in Indonesia is Bali sardinella fisheries. Bali sardinella (*Sardinella lemuru*) are pelagic fish that live in shallow sea waters, flocks or *schooling*, and include surface species. The habitat of coastal waters is suitable for Bali sardinella. The highest population of Bali sardinella fish in Indonesia is in the Bali Strait to East Nusa Tenggara (Putra *et al.*, 2020). Pengambengan Nusantara Fishing Port (NFP) located in Jembrana Regency, Bali is one of the landing places for Bali sardinella originating from the waters of the Bali Strait.

The production of Bali sardinella fisheries at Pengambengan NFP itself is very high. This has led to an increase in arrest efforts made without regard to the precautionary principle which has an impact on the sustainability or sustainability of these resources (Perdana, 2012). Increasing the intensity and catch efforts of Bali sardinella fisheries in the Bali Strait, especially at Pengambengan NFP, it is feared that they will experience more exploitation or capture. This makes it important to conduct a study to analyze the level of effort, catch, and economic rent of Bali sardinella fisheries in MSY, MEY, and OA conditions and analyze the optimal utilization rate of Bali sardinella fisheries. This is related to the study of Bali sardinella resource stocks in the waters of the Bali Strait, especially those landed at Pengambengan NFP.

2. Methods

2.1 Data Collection

The research was conducted in December 2022 - May 2023 at Pengambengan NFP (Fig. 1). Primary data were obtained from observations and direct interviews with fishermen, the information asked in the form of average costs for one fishing and the average selling price of caught fish. The secondary data required in this study is time series data from catches for the last 7 years obtained from Pengambengan NFP. This study used a quantitative approach to determine the value of Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access (OA) in Bali sardinella.

2.2 Data Analysis

The surplus production model is an important quantitative tool for estimating equilibrium points (Worm *et al.,* 2009; Hutchings *et al.,* 2010; Branch *et al.,* 2011). The surplus production model provides a more objective assessment of stock status than methods that are only on catch (Branch *et al.*, 2011). Compared to complex scoring models, these models require only a small number of available parameters and data. Periodic data on Bali sardinella production for the last 7 years (2015–2021) that have been collected are then analyzed to calculate the Catch per Unit Effort (CPUE) value (Gulland, 1983):

$$CPUE_t = \frac{catch_t}{effort_t(f_t)}$$

In Schaefer's model, the regression performed is $y = CPUE_t$; $x = effort_t\ (f_t)$, which t stands for year. The Schaefer surplus production model is a model used to predict the potential of Bali sardinella resources based on catch and fishing effort (Kuriakose *et al.*, 2006). According to Sparre and Venema (1992) the equation of the Schaefer linear model is:

$$CPUE_t = a + b(f_t)$$

$$MSY = -\frac{a^2}{4b}$$

$$E_{MSY} = -\frac{a}{2b}$$

Furthermore, Total Allowable Catch (TAC) and the level of utilization of fish resources can be determined by analysis of surplus production based on the precautionary principle (FAO 1995 in Syamsiyah 2010), so that:

$$TAC = \frac{80\%}{100\%} \times MSY$$

Where: MSY: Maximum Sustainable Yield (tons); E_{MSY}: Optimal capture effort (trip); TAC: Total Allowable Catch (tons).

2.3 Bioeconomic Analysis

The bioeconomic analysis used is the Gordon-Schaefer model, Gordon includes economic studies of the Schaefer model. This is to explain the relationship between fish resources by including the price per unit catch and cost per unit effort factors in the function equation, to describe biological-economic interactions. There are three equilibrium conditions in the Gordon-Schaefer model, those are Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access (OA). Static bioeconomic analysis based on the Gordon-Schaefer model can be performed by linear regression method with the following equation:

$$y = CPUE_t$$

$$x = effort_t(f_t)$$

$$CPUE_t = a - b(f_t)$$

Where: a: intercept; b: slope.

Table 1. Bioeconomic analysis formulas of various management regimes.

Variable	Category		
	MEY	**MSY**	**OA**
Effort (E)	$\left\|\frac{a}{2b} - \frac{c}{2bp}\right\|$	$\left\|-\frac{a}{2b}\right\|$	$\left\|\frac{ap - c}{bp}\right\|$
Catch (h)	$\left\|Emey\left(\frac{ap + c}{2p}\right)\right\|$	$\left\|-\frac{a^2}{4b}\right\|$	$Eoa\left(\frac{c}{p}\right)$
Profit (π)	$p.hmey - c.Emey$	$p.hmsy - c.Emsy$	$p.hoa - c.Eoa$

Where: TR: total revenue (Rp); TC: total cost (Rp); π: profit (Rp); p: average price of fish (Rp); h: catch (tons); c: cost per unit effort (Rp); E: effort (trip).

Economic parameters that influence the bioeconomic model in capture fisheries are the cost of catching (c) and the price of catch (p). Furthermore, the calculation of the utilization rate (UR) of Bali sardinella resources uses the following formula (Wahyudi, 2010):

$$UR = \frac{Yi}{MSY} \times 100\%$$

Where: Yi: yield of year-i (tons); MSY: maximum sustainable yield (tons).

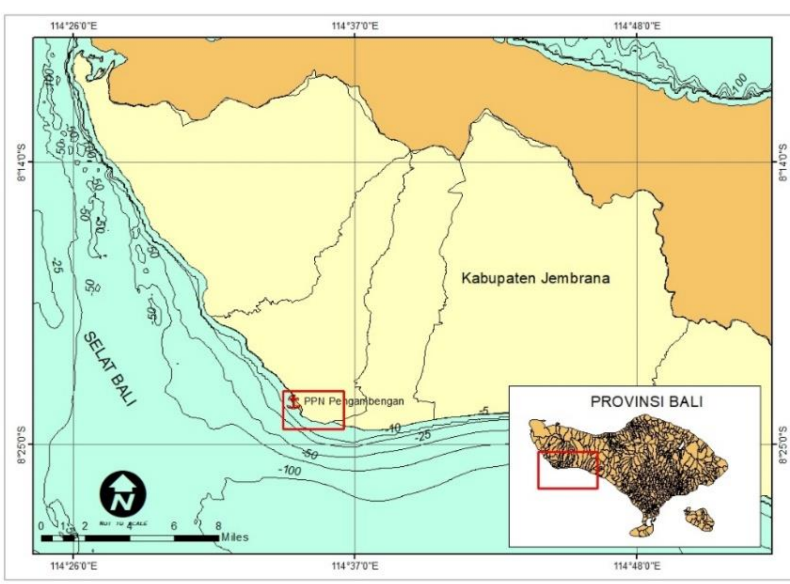

Fig. 1. Study site.

3. Results and Discussion

Based on the a and b values generated by the Schaefer Model regression, E_{MSY} results were obtained at 4,691 trips per year and MSY at 17,639 tons per year (Fig. 2). While Total Allowable Catch (TAC), which is 80% of the sustainable catch, is 14,111 tons per year.

The average utilization rate of Bali sardinella fishery resources (*Sardinella lemuru*) over the last 7 years is 59%. It is still below the point of optimal catch effort and sustainable potential (Table 2). This value is evidenced by the average catch or production for 7 years, which is 10,324 tons, lower than maximum sustainable yield (MSY). This shows that the utilization rate of Bali sardinella fishery resources at Pengambengan NFP is still sustainable. Likewise, the effort with an average of 3,794 trips is below the optimal catch effort (E_{MSY}). This status shows that the stock condition or utilization level of Bali sardinella fishery resources landed at Pengambengan NFP is still sustainable.

The year 2015 was the highest CPUE point (Fig. 3). Although CPUE dropped dramatically in 2016–2017, it increased again in 2018–2021. The decline in CPUE trends from 2016–2017 is an indicator of increased fishing efforts and a decrease in fish landing or fish production that year.

Based on Fig. 4, the relationship between effort and CPUE using the Schaefer model obtained an R^2 value of 0.0061. The intercept value (a) obtained is 3.1053 and the slope value (b) is -0.00008. The relationship between CPUE and Bali sardinella fishery catch efforts shows a negative correlation. The result of the linear equation CPUE = -0.00008f + 3.1053, shows that if the capture effort is increased, it will reduce the CPUE value, and vice versa. The value of the determinant coefficient (R^2) of the linear equation is 0.0061. The results showed that only 0.61% of the effect of the effort variable could be explained by the model, many other factors or variables not addressed in the study that affect CPUE.

Based on Fig. 5, the CPUE of Bali sardinella and scad fish experienced almost the same fluctuations and was inversely proportional to the CPUE of little tuna, fringescale sardinella and others. In general, fisheries production of Bali sardinella and other pelagic fishes was lowest in 2017. The production increased again from 2018 to 2019, then decreased until 2021.

The results also show that when Bali sardinella production is low, production is dominated by bycatch such as little tuna, scad, fringescale sardinella, and other types (Fig. 5 & 6). This result shows that several bycatch species with high selling value were also caught based on data from Pengambengan NFP.

The results of bioeconomic analysis using the Schaefer Model show that maximum profit is achieved at the point of optimal capture effort of E_{MEY} with a catch of MEY (Table 3). This indicates that E_{MEY} lower than E_{MSY} will provide maximum profit. This shows that an economic equilibrium point can be reached at the E_{MEY} point with a lower value compared to E_{MSY} so that the profits obtained are higher. In this case, an effort of 4,554 trips/year alone can generate maximum profit compared to the effort from E_{MSY} of 4,691 trips/year. In addition, bioeconomic analysis also shows that even with very high effort under EOA conditions will not produce maximum profit (Fig. 7).

The main fishing gear used to catch Bali sardinella at the Pengambengan Nusantara Fishing Port (NFP) is a small pelagic purse seine with two vessels. A small pelagic purse seine with two vessels is an active fishing gear that catches pelagic fish in groups/schooling (Wijayanto 2020; Wijayanto 2021).

Based on the Schaefer Model, the E_{MSY},

MSY, and TAC values are 4,691 trips per year; 17,639 tons per year; and 14,111 tons per year, respectively. Results of the previous study by Satyawan *et al.* (2023) obtained MSY and TAC 16,587 and 13,269 tons per year, respectively. The MSY and TAC of both studies are not much different. While study conducted by Listiani *et al.* (2016) obtained an MSY of 34,284 tons per year. The study by Listiani *et al.* used 6 years of production data (2010 – 2016) from the Pengambengan NFP and the Muncar Coastal Fishing Port (CFP), while this study used 7 years of production data (2015 – 2021) only from the Pengambengan NFP. This can affect the difference in study results obtained.

The average utilization rate of Bali sardinella Fishery resources (*Sardinella lemuru*) over the last 7 years is 59%. This value is still below the point of optimal capture effort and sustainable potential. Likewise, the effort with an average of 3,794 trips is almost close to the optimal catch effort rate (E_{MSY}). This is harmonized with previous research by Himelda *et al.*, (2011) which shows that the utilization of Bali sardinella resources for 6 years (2005-2010) is still within the permissible fishing capacity.

CPUE values in 2015 reached their highest value for the past seven years and declined dramatically in 2016–2017, then increased again in 2018–2021. The decline in CPUE trends from 2016–2017 is an indicator of increased fishing efforts and a decrease in fish landing or fish production that year. Maynou *et al.* (2003) explain that CPUE values describe species abundance and catch fluctuations. According to Weyl *et al.* (2010), CPUE variation is related to differences in the number of fishermen, working hours, and fishing gear categories. Low CPUE indicates a relatively low abundance of fish, this is related to an increase in the number of fishermen, trips, and low catches (Makwinja *et al.*, 2021).

The relationship between CPUE and Bali sardinella fishery catch efforts shows a negative correlation. A negative correlation indicates that an increase in the number of fishing efforts can lead to a decrease in productivity. However, Bali sardinella stock studies cannot be directly clinched from the comparison of production and effort, because CPUE is not a valid measure of abundance (Krisdiana *et al.*, 2013). Meanwhile, the results showed that the effort variable only described 0.61% of the CPUE value. The results of a previous study by Siegers (2016) also showed that 20.8% of effort affects the CPUE value.

The CPUE pattern of Bali sardinella landed at Pengambengan NFP over the past seven years shows fluctuations that are inversely proportional to the CPUE pattern of little tuna, fringescale sardinella, and others landed in the same location. This indicates that when the potential or production of Bali sardinella and scad is low, the production of other pelagic fish such as little tuna and fringescale sardinella is high.

The results of the bioeconomic analysis show that E_{MEY} lower than E_{MSY} will provide maximum profit. This is due to too high effort resulting in low production which has an impact on high expenditure costs, while the cost of receiving from the average price of the same fish is reduced. In Open Access (OA) conditions, profits will decrease and potentially reduce stock because the effort made has exceeded the limit of optimal capture effort or E_{MSY}. Earlier research by Siegers (2016), also stated that increasing fishing efforts can reduce the number of Bali sardinella stocks in the Bali Strait.

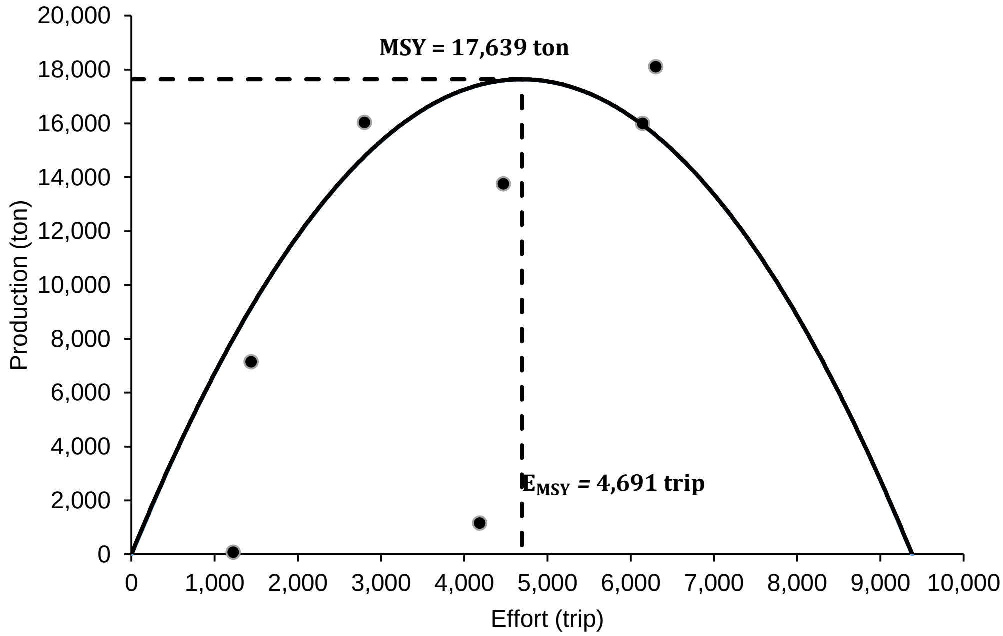

Fig. 2. **Stock equilibrium curve (MSY) of Bali sardinella (Sardinella lemuru) landed at Pengambengan NFP.**

Table 2. MSY and EMSY of Bali sardinella (Sardinella lemuru) landed at Pengambengan NFP with Schaefer linear model.

Year	Number of catches (tons)	Total standard effort	CPUE (Schaefer Model)	Utilization rates (%)
I	Yi	X	Y	UR
2015	16,038.0	2,801	5.7258	91%
2016	7,150.0	1,438	4.9722	41%
2017	76.5	1,224	0.0625	0%
2018	1,154.1	4,186	0.2757	7%
2019	16,002.9	6,141	2.6059	91%
2020	18,101.0	6,302	2.8723	103%
2021	13,747.6	4,469	3.0762	78%
Total	72,270.1	26,561	19.5906	
Average	10,324.3	3,794	2.7987	59%

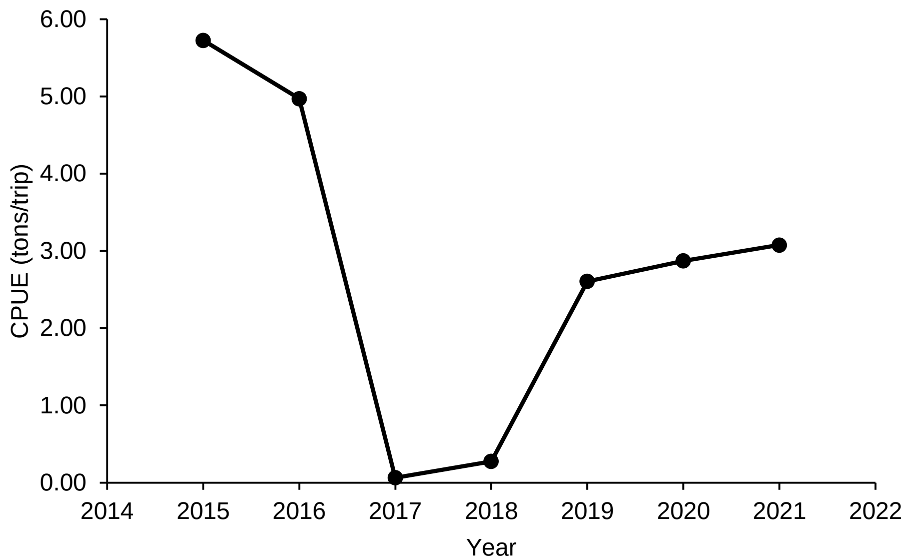

Fig. 2. CPUE fluctuation of Sardinella lemuru landed at Pengambengan NFP.

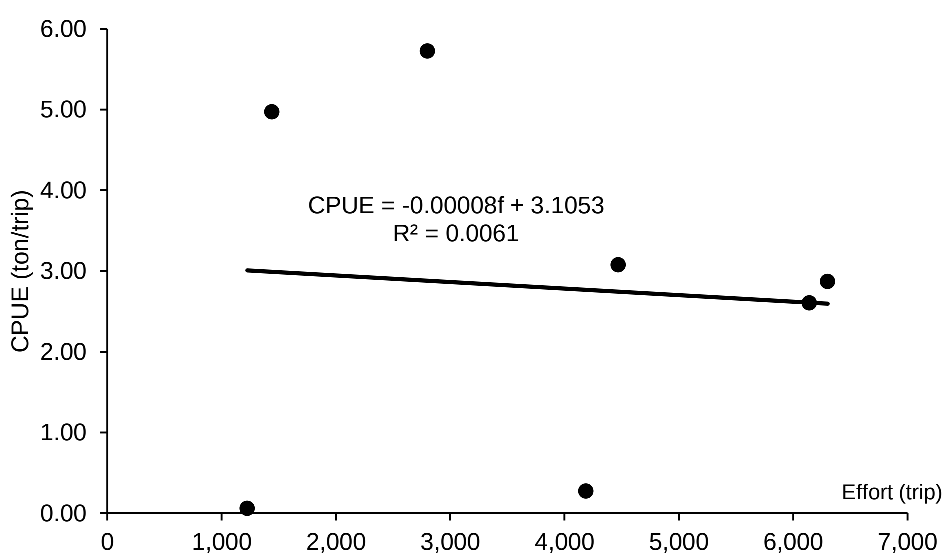

Fig. 3. Linear equations of CPUE and effort of Sardinella lemuru landed at Pengambengan NFP.

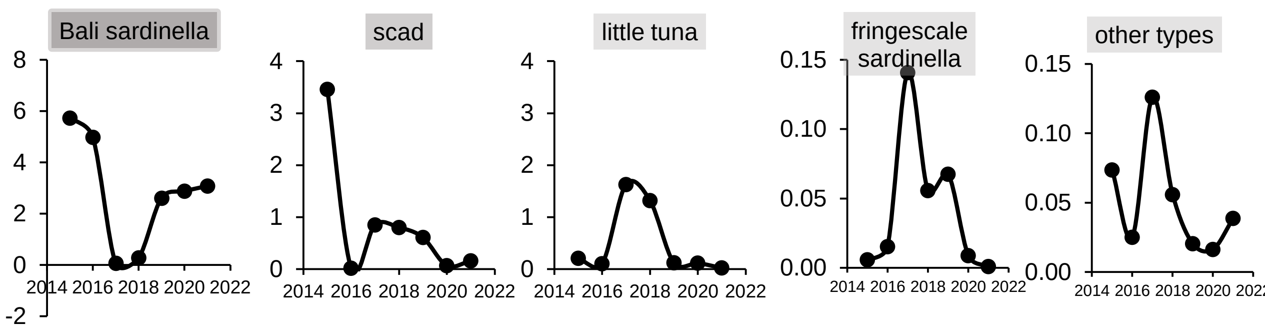

Fig. 4. CPUE pelagic fish landed at Pengambengan NFP.

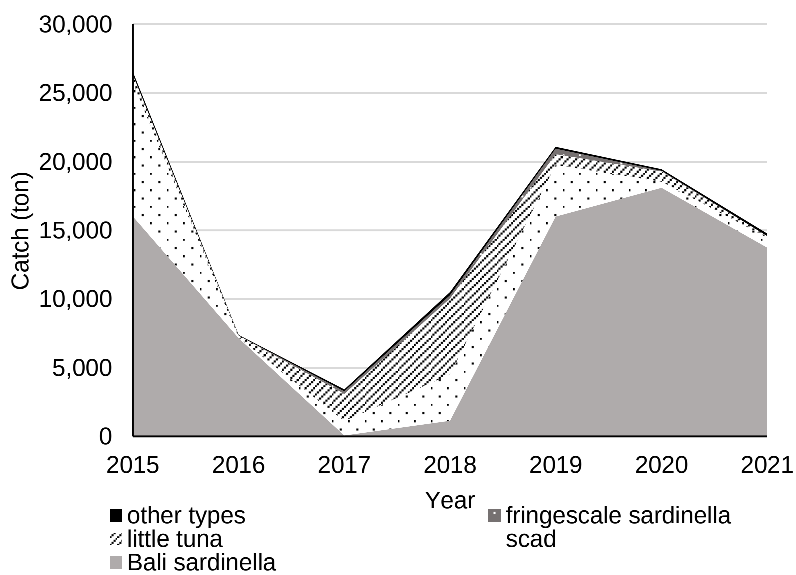

Fig. 5. Production of Bali sardinella fisheries and other pelagic fishes at Pengambengan NFP.

Table 3. Results of bioeconomic analysis of Bali sardinella resources (Sardinella lemuru) landed at NFP Pengambengan using the Schaefer Model.

Category	Catch (h)	Effort (E)	TR = p x h (Rp)	TC = c x E (Rp)	Profit (Rp)
MEY	17,624	4,554	79,942,020,349	4,553,859,332	75,388,161,017
MSY	17,639	4,691	80,010,789,883	4,691,398,400	75,319,391,483
OA	2,008	9,108	9,107,718,664	9,107,718,664	0

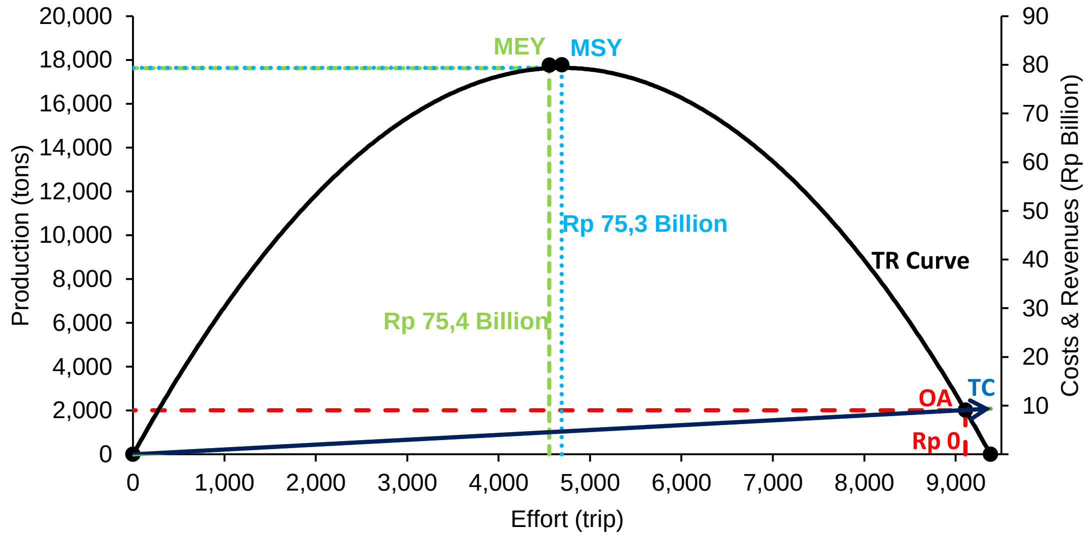

Fig. 6. Bioeconomic analysis of Bali sardinella (Sardinella lemuru) landed at Pengambengan NFP using the Schaefer Model.

4. Conclusions

The condition of Bali sardinella fishery stocks at Pengambengan NFP based on the average catch effort and the actual catch is still below the optimal balance point. Fishing efforts and actual catches of Bali sardinella fisheries by fishermen are still below E_{MEY} and MEY points based on bioeconomic predictions.

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دراسة مخزون مصايد أسماك سردينيلا في بالي بميناء صيد الأسماك بينغامبينجان نوسانتارا، بالي

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المستخلص. يعد تقييم الأرصدة أحد الجهود المبذولة لمعرفة تأثير وتأثير أنشطة الصيد على الأرصدة السمكية والسكان. إحدى الموارد السمكية التي لها قيمة اقتصادية مهمة في إندونيسيا هي مصايد أسماك السردينيلا في بالي. يشجع الإنتاج المرتفع لمصايد أسماك السردينيلا في بالي في ميناء بينغامبينجان نوسانتارا لصيد الأسماك على زيادة كثافة وجهود الصيد، لذلك يخشى حدوث استغلال مفرط. تستخدم هذه الدراسة البيانات الأولية والبيانات الثانوية من Pengambengan NFP، لتحليل مستوى الجهد والصيد والإيجار الاقتصادي لمصايد أسماك السردينيلا في بالي في ظل ظروف MSY و MEY و OA. نتيجة المعادلة الخطية CPUE = -0.00008f + 3.1053، إذا زاد جهد الالتقاط سيقلل من قيمة CPUE، والعكس صحيح. حصلت نتائج الانحدار لنموذج شيفر على نتائج EMSY لـ ٤,٦٩١ رحلة سنويًا، و MSY 17,639 طنًا سنويًا، و TAC 14,111 طنًا سنويًا. حصلت نتائج تنبؤ نموذج الاقتصاد الحيوي على قيم EMEY و MEY، وهي ٤,٥٥٤ رحلة سنويًا و ١٧,٦٢٤ طنًا سنويًا.

الكلمات المفتاحية: سردينيلا ليمورو، MSY، MEY، الزراعة العضوية، إندونيسيا.