Assessment of the utilization status of fourfinger threadfin (*Eleutheronema tetradactylum*) in the waters of Dumai City, Riau Province

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Abstract. One of the local fish species exploited in the waters of Dumai is fourfinger threadfin (*Eleutheronema tetradactylum*). The purpose of this research is to analyze the maximum sustainable yield, optimal efforts, and utilization levels of fourfinger threadfin. Data on catches and efforts were collected from the annual reports of the Department of Fisheries Dumai City over a period of ten years. The results of the analysis using the Walter-Hilborn model indicate that the maximum sustainable yield of fourfinger threadfin is 234 ton year^{-1}, and the optimal effort (E_{opt}) is 404 unit year^{-1}. The average utilization rate of fourfinger threadfin from 2014 to 2023 is 28 percent. The resource is currently moderately exploited (25-75%), indicating that the stock has been harvested close to its maximum sustainable yield value. It is advisable to increase fishing efforts without compromising the sustainability of fourfinger threadfin in the waters of Dumai City.

1 Introduction

Indonesia is an archipelagic country with a maritime territory that is larger than its land area, comprising nearly two-thirds of its total expanse [1-2]. The vast expanse of water in Indonesia makes the fisheries sector one of the key areas relied upon for economic development [3-4]. To position the fisheries sector as a cornerstone of economic development, it is essential for this sector to be recognized as a national flagship. Additionally, it is important to persuade all economic stakeholders of the potential and capabilities of the maritime and fisheries industry [5-6].

Dumai City is a district located in Riau Province and is part of the fishing area designated as WPP 571 [7]. Dumai City has great potential and is a major producer of fisheries in Riau

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Province. The waters of Dumai represent a strategically significant and highly promising fishing center, particularly in the realm of capture fisheries [8]. This is further supported by the existence of fish landing bases, which serve as designated locations for fishermen to offload their catches. The catch includes economically valuable fish, one example being the fourfinger threadfin. Fishermen exploit this species using gill nets.

The fourfinger threadfin is one of the most promising catches in the waters of Dumai due to its year-round availability and high economic value. This species inhabits a variety of environments, including muddy, sandy, clay, and rocky coral waters. The fourfinger threadfin is capable of tolerating varying salinity levels, thriving in estuarine waters, and even entering freshwater rivers [9-10]. BPS-Statistics Dumai City reported that the production of fourfinger threadfin from 2014 to 2023 has shown an increasing trend. This rise in the number of fourfinger threadfin raises concerns about the potential for overfishing, which could threaten the population of fourfinger threadfin in Dumai waters and its surrounding areas.

Fish resources, including fourfinger threadfin, possess the ability to renew themselves through growth and reproduction. However, as a common property resource, their utilization is freely accessible to anyone [11]. The high market demand for fourfinger threadfin stock can lead to increased fishing efforts aimed at exploiting this species without regard for sustainability. Therefore, the fourfinger threadfin resources in Dumai waters must be managed effectively to ensure maximum benefits for the community in a sustainable manner. Good management of fourfinger threadfin fish resources can be achieved by understanding their potential in the waters. This research aims to identify the most suitable surplus production model for the characteristics of fourfinger threadfin, analyze the maximum sustainable yield (MSY), and assess the optimal utilization status of fourfinger threadfin in Dumai waters. The findings of this research are expected to provide valuable information for fishermen, fourfinger threadfin catchers, and relevant agencies.

2 Material and methods of research

2.1 Type and source of data

The types and sources of data utilized in this research include both primary and secondary data. Primary data were collected directly in the field, focusing on the characteristics of the fourfinger threadfin, fishermen, and other relevant factors. This primary data collection involved direct interviews with fishermen and various stakeholders. In contrast, secondary data were sourced from various institutions, encompassing production statistics, fishermen demographics, types of fishing gear, and the fleet of vessels employed.

2.2 Data collection

The method employed in this research is a survey approach. A field survey was conducted in Dumai City, which was selected as the research location through purposive sampling, given that Dumai is a coastal area and the largest center for capture fisheries production in Riau Province. Time series data spanning a period of ten years, from 2014 to 2023, were utilized. The data has been entered and processed using the Microsoft Excel program. The data processing involves calculating the catch per unit effort (CPUE) value. Additionally, surplus production model analysis has been performed using five models: Schaefer, Fox, Walter-Hilborn, Schnute, and Clarke Yoshimoto Pooley (CYP). Each of these models has a coefficient of determination (R^2) value, and the model with the highest R^2 has been used as a reference for assessing the status of the fourfinger threadfin stock.

2.3 Data analysis

This research employs a surplus production model approach. The estimation of the potential yield of fourfinger threadfin is based on the catch volume and the variation in fishing gear utilized. The estimation procedure is conducted through the following steps [12]:

1. Calculating catch per unit effort, through the equation:

$$CPUE = \frac{Catch}{Effort} \quad (1)$$

where:

Catch = the total catch of fourfinger threadfin
Effort = the number of capture attempts used

2. Maximum sustainable yield

To calculate the maximum sustainable yield and the effort optimal (E_{opt}), five types of models can be utilized, namely:

a. Schaefer (1954) [13]

$$E_{opt} = -\frac{\alpha}{2} \quad (2)$$

$$MSY = -\frac{\alpha^2}{4b} \quad (3)$$

b. Fox (1970) [14]

$$E_{opt} = -\frac{1}{b} \quad (4)$$

$$MSY = -\frac{1}{b} exp\ (\alpha\text{-}1) \quad (5)$$

c. Schnute (1977) [15]

$$E_{opt} = -\frac{\alpha}{2b} = -\frac{r}{2q} \quad (6)$$

$$MSY = -\frac{\alpha^2}{4b} = -\frac{rK}{4} \quad (7)$$

d. Walter-Hilborn (1992) [16]

$$E_{opt} = -\frac{\alpha}{2b} = -\frac{r}{2q} \quad (8)$$

$$MSY = \frac{\alpha^2}{4b} = \frac{rK}{4} \quad (9)$$

e. Clarke Yoshimoto Pooley (1992) [17]

$$E_{opt} = \frac{r}{q} \quad (10)$$

$$MSY = \frac{rK}{e} \quad (11)$$

3. Utilization rate [18-19]

$$TP(i) = \left(\frac{Ci}{MSY}\right) x\ 100\% \quad (12)$$

where:
α = intercept
b = slope
r = intrinsic growth rate
q = catchability coefficient (ton unit^{-1})
K = carrying capacity (ton year^{-1})
E_{opt} = effort in year-i (unit)
C_i = production in the period-i (ton)

MSY = maximum sustainable yield (ton unit^{-1})

4. Total allowable catch (TAC)

Based on the international commitment established by FAO in the Code of Conduct for Responsible Fisheries (CCRF), the potential of marine resources that can be sustainably utilized is approximately 80 percent of the maximum sustainable yield [20-21]. Consequently, the total allowable catch (TAC) can be calculated using the following formula:

$$TAC = MSY \times 80\% \quad (13)$$

3 Results

3.1 Catch per unit effort (CPUE)

Catch per unit effort (CPUE) is a metric that reflects the productivity of gill net fishing gear. The productivity of fishing gear is defined as the catch weight per unit of fishing effort, making the CPUE a valuable indicator of productivity [22]. In this study, the CPUE is calculated by comparing the total annual production in tons to the total fishing effort measured in units. The CPUE value for fourfinger threadfin in the waters of Dumai is presented in Table 1.

Table 1. CPUE value for fourfinger threadfin.

Year	Production (ton year^{-1})	Effort (ton unit^{-1})	CPUE (ton unit^{-1})
2014	19	69	0.924
2015	24	85	0.953
2016	34	107	1.057
2017	42	116	1.231
2018	56	134	1.409
2019	47	162	0.987
2020	64	178	1.212
2021	60	281	0.718
2022	87	269	1.093
2023	86	305	0.952

Table 1 presents the catch per unit effort (CPUE) values for fourfinger threadfin from 2014 to 2023. Throughout this period, the CPUE values demonstrated significant fluctuations. These variations in CPUE reflect changes in the productivity and catch conditions of fourfinger threadfin, which can be influenced by factors such as environmental changes, overfishing, and fish population dynamics. CPUE is affected by the amount of effort exerted throughout the year to produce the catch. In addition to the distance of the fishing grounds, other factors that influence CPUE include environmental conditions such as seasonal variations and salinity levels [23].

3.2 Relationship between CPUE and effort

The relationship between catch per unit effort (CPUE) and effort is illustrated through regression analysis using production data for fourfinger threadfin collected over a ten year period from 2014 to 2023. The graph depicting the relationship between CPUE and effort for fourfinger threadfin in the waters of Dumai is presented in Figure 1.

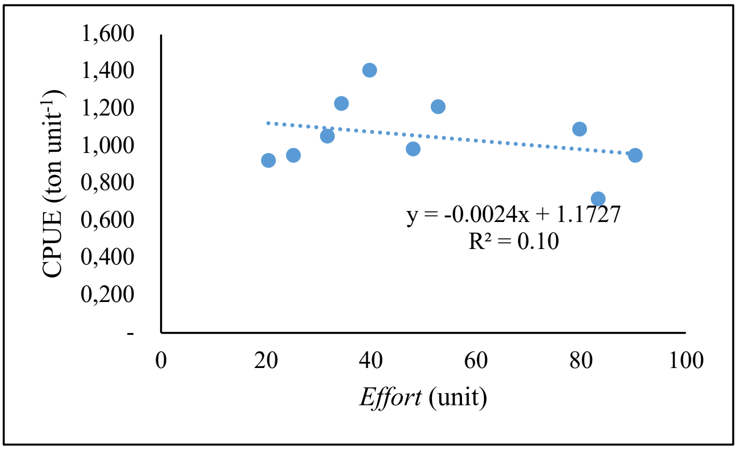

Fig.1. Relationship between CPUE and effort of fourfinger threadfin from 2014 to 2023.

Based of Figure 1, the analysis of the relationship between CPUE and effort for fourfinger threadfin resulted in a linear equation: Y = -0.0024x + 1.1727. This equation indicates that the constant (a) is 1.1727, suggesting that the potential yield available in nature, without any fishing effort, is still 117.27 tons $unit^{-1}$. The regression coefficient (b) is -0.0024x, indicating a negative relationship between CPUE and effort. This suggests that a decrease of one unit in effort will result in an increase of 0.24 tons in CPUE, and conversely, an increase in effort will lead to a decrease in CPUE. The coefficient of determination (R^2) of 0.10 indicates that 10% of the decrease in production is attributable to the effort (x), while 90% of the decline in catch production is due to other factors not included in the study. R^2 value is utilized to assess the goodness of fit of a regression model and to evaluate the validity of the regression results in relation to the dependent variable. A higher R^2 value signifies a more effective model. The R^2 value ranges from 0 to 1, with model fit considered superior as the R^2 value approaches 1 [24-25].

3.3 Surplus production model

The surplus production model is a well-established framework in fisheries literature and has been employed for over forty years [26]. This model is favored not only for its relative simplicity but also because it requires only data on catch results and fishing effort time series, which are typically available at all fish landing sites. The sustainable potential of fourfinger threadfin in the waters of Dumai is estimated using the surplus production model. This model is the simplest in fish population dynamics, treating the population as a single, indivisible biomass that follows straightforward rules of growth and decline. The result obtained from the estimation represents the maximum allowable catch necessary to sustain the resources of capture fisheries.

This study employs five models to determine maximum sustainable yield (MSY): Schaefer (1954), Fox (1970), Clarke Yoshimoto Pooley (CYP) (1992), Schnute (1977), and Walter-Hilborn (1992). Among these five models, the most suitable one is selected based on the other estimates. Surplus production model formulas are applicable only when the slope parameter (b) is negative. This indicates that an increase in fishing effort will result in a decrease in catch per unit effort (CPUE). Conversely, if the parameter b is positive, it becomes impossible to estimate the size of the stock or the optimal effort. However, it can be concluded that increasing fishing effort may still lead to higher catches [27]. The results of the surplus production model analysis for the five models used to calculate the maximum sustainable potential value are presented in Table 2.

Table 2. The results of the surplus production model analysis for the fourfinger threadfin.

Parameters	Schaefer	Fox	CYP	Schnute	Walter-Hilborn
Intercept (a)	1.263	0.161	0.207	0.025	1.290
X_1 (b)	-0.003	-0.002	-0.177	0.028	-1.114
X_2 (c)	-	-	-0.002	-0.001	-0.002
R^2	0.10	0.11	0.15	0.01	0.60
E_{opt} (unit year^{-1})	231	407	374	11	404
MSY (ton year^{-1})	146	176	164	-5.085	234
TAC (ton year^{-1})	117	141	131	-4.06	187
Intrinsic growth rate (r)	-	-	2.861	0.025	1.290
Catchability coefficient (q)	-	-	0.008	0.001	0.002
Carrying capacity (K)	-	-	155.93	-809.92	725

Based on the analysis of five surplus production models, the Walter-Hilborn model is the most suitable for managing fourfinger threadfin, as it has the highest R^2 value of 0.60 among the models analyzed. The coefficient of determination (R^2) is commonly used to assess the goodness of fit of a regression model and to compare the validity of regression results for independent variables within the model. A larger R^2 value indicates a better-fitting model [28-29]. From the regression coefficient values, the environmental carrying capacity (K) of 725 tons indicates that the biological aspect of the Dumai water environment can support a production of 725 ton year^{-1} of fourfinger threadfin. The catchability coefficient (q) of 0.002 suggests that each unit increase in fishing effort will result in a 0.002 ton impact on the fourfinger threadfin catch. The intrinsic growth rate (r) of 1.290 ton year^{-1} indicates that the natural growth rate of the fourfinger threadfin population, when undisturbed by natural factors or human activities, is 1.290 ton year^{-1}.

3.4 Maximum sustainable yield of fourfinger threadfin

The fourfinger threadfin is one of the many fish species found in the waters of Dumai City. This fish holds significant economic value and serves as an important export commodity. The capture of fourfinger threadfin is primarily conducted using gill nets. The maximum sustainable yield (MSY) represents the threshold at which fourfinger threadfin resources can be harvested without disruptive their sustainability for future regrowth. The MSY curve for the fourfinger threadfin is illustrated in Figure 2.

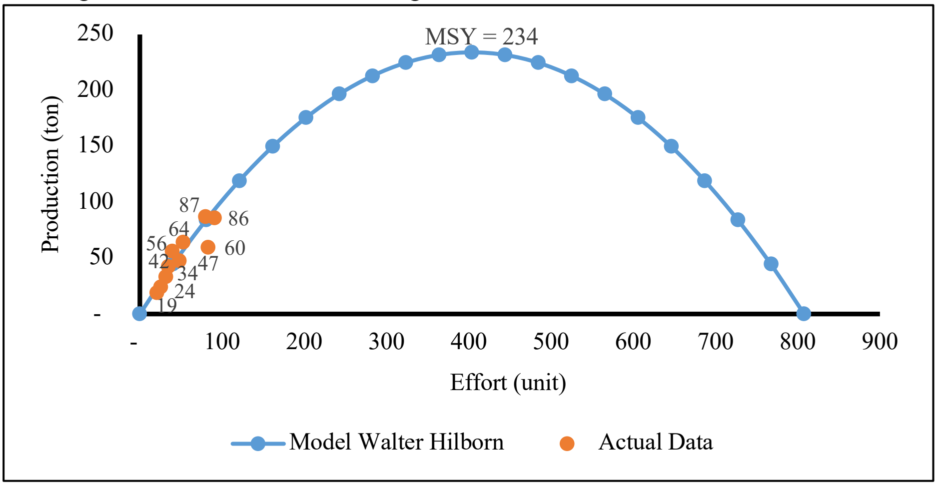

Fig.2. Maximum sustainable yield for fourfinger threadfin using the Walter-Hilborn model.

Figure 2 illustrates the maximum sustainable yield of fourfinger threadfin in the waters of Dumai, as determined by calculations from the surplus production model using the Walter-Hilborn (WH) approach. The optimal effort value (E_{opt}) for catching fourfinger threadfin in Dumai waters is 404 unit year^{-1}, with a maximum sustainable yield (MSY) of only 234 ton year^{-1}. This MSY value represents the threshold at which fourfinger threadfin resources can be utilized without compromising their reproductive sustainability. Over a period of ten years (2014-2023), the utilization rate of fourfinger threadfin in Dumai waters is 28 percent, indicating that the resource is moderately exploited (75%-100%). This suggests that the fourfinger threadfin stock is being exploited close to the MSY value. Therefore, increasing fishing effort is strongly discouraged, even though catches may still rise, as this could jeopardize the sustainability of the fourfinger threadfin population.

3.5 Utilization rate

The utilization rate refers to the proportion of fish resources that have been harvested over a specific time period. To assess the utilization status of fourfinger threadfin in the waters of Dumai, we employed the FAO method (1995), which categorizes the utilization status of fishery resources into six groups [30]: unexploited (0%), lightly exploited (<25%), moderately exploited (25-75%), fully exploited (75-100%), overexploited (100-150%), and depleted (>150%). The utilization rate is calculated by dividing the catch by the maximum sustainable yield (MSY) value derived from the Walter Hilborn model, expressed as a percentage. This information is presented in Table 3.

Table 3. The utilization rate of fourfinger threadfin in the waters of Dumai from 2014 to 2023.

Year	Production (ton)	Total Allowable Catch (ton)	Utilization rate (%)	Utilization status
2014	19	187	10	light exploited
2015	24	187	13	light exploited
2016	34	187	18	light exploited
2017	42	187	23	light exploited
2018	56	187	30	moderately exploited
2019	47	187	25	moderately exploited
2020	64	187	34	moderately exploited
2021	60	187	32	moderately exploited
2022	87	187	47	moderately exploited
2023	86	187	46	moderately exploited
Average	52	187	28	moderately exploited

Based on Table 3, the average utilization rate of fourfinger threadfin in the waters of Dumai over the past ten years is 28 percent. This indicates that the catch is in a state of moderately exploited, suggesting that the stock of fourfinger threadfin is nearing its maximum sustainable yield (MSY). While increasing fishing efforts is still recommended to optimize yield, it is essential to regulate the capture. Fisheries resources are considered to be underfished if the utilization remains below the total allowable catch value, specifically less than 80% of the MSY [20, 31].

The utilization of fishery resources holds significant potential and presents opportunities for development to enhance the community's economy, particularly when the utilization level remains low (below the maximum sustainable yield). However, if the utilization rate is already high, increasing fishing efforts should be avoided, as this could lead to overfishing.

To optimize utilization opportunities, it is essential to manage the number of fishing trips within a shorter timeframe and to implement the use of larger mesh size nets to minimize bycatch, particularly of small fish [32].

4 Conclusions

The surplus production model indicates that the production of fourfinger threadfin in the waters of Dumai has fluctuated significantly over the past ten years. The most suitable surplus production model for managing fourfinger threadfin is the Walter-Hilborn model. This model provides reliable estimates for maximum sustainable yield (MSY), optimum effort (E_{opt}), and total allowable catch (TAC). The estimated MSY is 234 ton year^{-1}, E_{opt} is 404 unit year^{-1}, TAC is 187 ton year^{-1}, and the utilization rate is 28 percent. These results suggest that the fishing effort for fourfinger threadfin has not led to overfishing. Therefore, implementing effective management strategies is crucial to prevent overfishing and ensure the sustainability of fourfinger threadfin populations. Continuous monitoring and adjustments in fishing efforts should be conducted to maintain a balance between resource utilization and conservation.

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