Estimation of Frigate Tuna (Auxis thazard) resource potential from Sibolga Waters

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Abstract. Frigate Tuna (Auxis thazard) is one of commercial production of large pelagic fish fisheries in Sibolga Waters. The high demand for this fish has led to large-scale fishing practices that can disrupt the balance of fish populations in nature. Therefore, the objectives of the present study were to determine the maximum sustainable potential (Maximum Sustainable Yield), optimum effort (f_{opt}), and to find out the level of utilization, effort and catch of Frigate Tuna allowed. The secondary data analysis was using the Fox model. The results showed that the sustainable potential (MSY) of Frigate Tuna resources from Sibolga Waters amounted to 7,664.108239 kg/year with f_{opt} value was 2,539.025526 trips/year. utilization rate over the past 5 years has an average value of 153.2106% and an effort rate of 123.01%. It is concluded that the utilization resource level of Frigate Tuna from Sibolga Waters has been overfishing.

1. Introduction
Catch fisheries business is the foundation of most of the population who live in the coastal areas of Sibolga City [1]. One of the major pelagic fisheries productions in the Sibolga Waters is Frigate Tuna (Auxis thazard). Frigate Tuna is a commercial fish with high demand in the market. Arrest activities carried out on a large scale. Such large-scale fishing can disrupt the production of this fish and reduce its population in Sibolga Waters, especially if the fishing was done at any time.

However, the regulation of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia (71/PERMEN-KP/2016), concerning Fishing Tracks and Placement of Fishing Equipment in the Republic of Indonesia's Fisheries Management Area, fishing vessels that use forbidden fishing gear such as the trawls must replace their fishing gear become to the purse seine. This thing has become one of the factors that can reduce pelagic fish production, because increasing fishing fleets are being used would decrease the catch of pelagic fish, especially the Frigate Tuna. Supposedly, these marine fisheries resources need to be preserved and that they can be used continuously and can also be enjoyed by future generations [2].

Based on the introduction, in order to avoid excessive levels of exploitation while maintaining the viability and potential for sustainability as well as the sustainability of Frigate Tuna (Auxis thazard), kindly sustainable management is needed according to information about the fish in order to facilitate management and sustainability efforts in accordance with the conditions of the activity large-scale fishing found from Sibolga Waters. Therefore, this study aims to determine the maximum sustainable potential (Maximum Sustainable Yield), optimum effort (f_{optimum}), the level of utilization, exploitation and catch of resources of Frigate Tuna (Auxis thazard) allowed from Sibolga Waters.
2. Methods

This research was conducted in May to June 2019 at the Sibolga Archipelago Fisheries Port (Figure 1). The method used is descriptive method with secondary data support in the form of production data per fish species per year, production per fishing gear per year, and the number of fishing gear in Sibolga city from the Sibolga Archipelago Fisheries Port from 2014 to 2018.

![Figure 1. Map research](image)

The secondary data analysis uses the Schaefer and Fox model that is processed with Microsoft Excel 2007. Model Schaefer and Fox is a regression analysis model of CPUE to the amount of effort, to determine the maximum potential of sustainable (MSY) and effort optimum ($F_{opt}$) of the Frigate Tuna.

a. The productivity of a fishing gear can be assumed by looking at the relationship between the catch and the effort called the CPUE. The equation for finding CPUE values was calculated using the following formula [3]:

$$ CPUE = \frac{C_i}{f_i} \quad (1) $$

b. To find out the sustainable maximum potential (MSY) and optimum effort ($F_{opt}$) of Frigate Tuna, the data is processed through Schaefer Model and Fox Model approaches.

1) Schaefer model

The relationship between $C$ (catch) and $f$ (fishing effort) is:

$$ C = af + b (f)^2 \quad (2) $$

The optimum effort value ($F_{opt}$) is:

$$ F_{opt} = -\left(\frac{a}{2b}\right) \quad (3) $$

Sustainable Maximum Potential Value (MSY) is:
\[ MSY = -\frac{a^2}{4b} \]  

(4)

c. Estimation of the utilization level and effort were carried out to determine the value of the utilization level as well as the utilization of Frigate Tuna resources. The equation of utilization level is as follows [4]

\[ TPC = Ci \times \frac{100}{MSY} \]  

(5)

The equation of the level of effort is:

\[ TPt = \frac{f}{f_{opt}} \times 100\% \]  

(6)

d. The total allowable catch (TAC) can be determined by analysing the production surplus using the following formula terminated with production surplus analysis were using the following formula [5]:

\[ TAC = 80\% \times MSY \]  

(7)

3. Result and discussion

3.1. Frigate Tuna *(Auxis thazard)* production

The production estimate of Frigate Tuna resources in 2014 - 2018 from each fishing gear in the last 5 years landed at the Sibolga Archipelago Fisheries Port can be seen in Figure 2 and Figure 3.

The year of 2015 was the highest production of 3,581,734 tons while the lowest amount of fish production in 2017 was found total production of 953 tons. Based on production per fishing gear, pure seine dominates the production yield of Frigate Tuna for the last 4 years. While the lowest fishing gear production occurs in stretching fishing gear.

![Figure 2. The production of Frigate Tuna *(Auxis thazard)* in 2014 to 2018 at Sibolga Archipelago Fishery Port](image-url)
Figure 3. The production of Frigate Tuna (*Auxis thazard*) per fishing gear in 2014 to 2018

The yield of Frigate Tuna (*Auxis thazard*) during the last 5 years tends-of fluctuate. The highest production occurred in 2015 was due to the abundance of fish stocks and the increasing use of number of several types and diversity of fishing gear were used. While the lowest production occurred in 2017 due to the reduction in the number of fishing gear and the low diversity of fishing gear. Based on data from the production of fish Frigate Tuna per fishing gear, pure seine has dominated past of five years ago. This is due to the large number of those fishing gear catching units compared to other fishing gear in Sibolga, the purpose was to catch the schooling pelagic fishes. Pure seine is a fishing gear used to catch schooling pelagic fishes such as: bloated, lemuru, kite, mackerel, skipjack, and others [6].

The lowest of production is on stretching fishing gear. This is due to the small number of stretching fishing gear that catch Frigate Tuna. According to fishermen in Sibolga, this fishing line is mainly catching demersal fish and small pelagic fish. However, in recent years fishing vessels have begun to developed were using stretching lines as the main fishing gear with large pelagic fish catches.

3.2. Catching effort of Frigate Tuna (*Auxis thazard*)

Each fishing gear has decreased and increased the amount of effort every year. Based on the amount of effort on 3 types of fishing gear, purse seine has the highest effort in 2014 to 2018. While the lowest effort from 2014 to 2018 is on hand line.

Figure 4. Effort of Frigate Tuna (*Auxis thazard*) during 2014 to 2018
Effort of each fishing gear tends to increase every year and is dominated by purse seine. This can indicate that purse seine is a fishing gear that is used actively during the day and night by fishermen in Sibolga. Pure seine used reached a percentage of 87.30% over the past 5 years. This fishing gear is able to catch pelagic fish in large numbers, so that the fishermen are more dominant using pure seine. In increasing the fishing effort is done by increasing the size of the ship used [7].

The low effort of hand line is due to the small vessels and only has 3-5 crew members. The productivity of fishing vessels is influenced by the size of the vessel, the type of material, the strength of the vessel’s engine, the type of fishing gear used, the number of fishing operation trips per year, fishing capability, average catch per trip and fishing area [8].

### 3.3. Sustainable Potential Estimation (MSY) and Optimum Effort

Based on the analysis of the potential resources of Frigate Tuna (*Auxis thazard*) with the surplus production method were using the Schaefer model, linear regression between effort and CPUE (Figure 5), obtained a constant (a) of 1.318398049 and a regression coefficient (b) amounting to -0.000252705. The results of the sustainable potential estimation (MSY) of Frigate Tuna (*Auxis thazard*) amounted to 1,719.567244 tons/year with optimum effort of 2,608.57068 trips/year. Based on regression analysis, the coefficient of determination ($R^2$) were 0.7226.

The relation between the catch (C) with the catch effort (f) of Frigate Tuna (*Auxis thazard*) is shown using the Schaefer model in the equation $C = 1.318398049 - 0.000252705 \cdot f^2$. The relation between CPUE and efforts of the Schaefer model linear regression equation is $y = -0.0002x + 1.3184$ with $R^2 = 0.7226$ which means that every increase from 1 trip effort, then CPUE will decrease by 0.000252705 tons/trip.

The MSY for the Frigate Tuna (*Auxis thazard*) was 1,719.567244 tons/year, while the optimum effort ($f_{opt}$) of 2,608.57068 trips/year, which means that if the effort is done beyond optimum effort, it will reduce the value of production.

### Figure 5. Fox Model linear regression between effort and ln CPUE of Frigate Tuna (*Auxis thazard*)

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Estimating the potential of Frigate Tuna after being analysed using the Schaefer and Fox model, the coefficient of determination ($R^2$) on the Schaefer model is greater or closer to 1, that is 0.7226. This value indicates that there is a strong close relationship between production and effort compared to the value of the coefficient of determination of the Schaefer model. The model which has a coefficient of determination ($R^2$) greater indicates that the model has a closer relationship with the actual model [9].

MSY of Frigate Tuna in the last 5 years is 1,719.657244 kg/year. MSY is a management parameter produced in the assessment of fisheries resources [10]. MSY is used in the management of fisheries resources that are still possible to be exploited without reducing the population, it aims to keep the
stock of fisheries resources in a safe level. The concept is based on a very simple model of a fish population that is considered a single unit.

**Figure 6.** Maximum Sustainable Yield (MSY) and optimum effort of Frigate Tuna (*Auxis thazard*) (Fox model).

Total Allowable Catch (TAC) of Frigate Tuna was 1,375.654 tons/year. This value showed that fishing for Frigate Tuna can still be increased to be able to obtain optimal results. This is in accordance with the statement of [5] that TAC can be determined by an analysis of surplus production. The amount of TAC is usually calculated based on the MSY value of a fishery resource whose calculation is obtained from 80% of the maximum lestation potential.

The MSY of Frigate Tuna is 1719.567244 tons/year, while optimum effort \( (f_{opt}) \) of 2608.570686 trips/year. That is, if the effort exceeds the optimum effort, it will reduce the value of production. In 2018, effort amounted to 4050 trips/year with production of 1,956.600 tons/year and had exceeded optimum effort, so that production was smaller compared to 2014 which had effort of 976 trips/year with production of 995.181 tons/year. In 2018, the resources of Frigate Tuna have been overfishing due to the level of effort that exceeds the optimum effort so that production is less compared to 2014 (Figure 6).

The highest CPUE value occurred in 2014, amounting to 1,020 tons/trip with the number of the catch of Frigate Tuna was 995.181 tons and the fishing effort was 976 trips. The lowest CPUE value occurred in 2017, amounting to 0.225 tons/trip with a total catch of 766.970 tons of Frigate Tuna and a fishing effort was 3011 trips. Fluctuations in CPUE value are influenced by the amount of effort done by fishermen. The higher of the catch effort would influenced the lower of the catch and the CPUE value will also decrease.

### 3.4. Estimation of utilization and effort level

The utilization and effort level of Frigate Tuna in 2014 was 57.87 % with an effort rate of 37.2%, while in 2015 the utilization rate increased to 97.31 % with the level of effort increasing to become amounting to 68.04 %, this can be interpreted that efforts still need to be improved.

In 2016, the reuse rate increased with a value of 110.91% and an effort rate of 75.41%, while in 2017 the reuse rate decreased 44.60% with an effort rate of 115.43%. In 2018, it has increased again by 56.35%, which became 100.95% with an increase in the effort rate of 155.26% (Figure 7).
Figure 7. Rate of utilization and effort level of Frigate Tuna (Auxis thazard)

The level of utilization and effort of Frigate Tuna in 2014 and 2015 has not reached 100%, which means the utilization and effort of Frigate Tuna is still at a moderate level. In 2016 the value of utilization rate was 110.91%, which means the level of utilization of Frigate Tuna in 2016 had experienced overfishing. While the level of effort in 2016 has not reached 100%, so that the level of over-utilization or overfishing has occurred which could threaten the extinction of the resources of the Creted Fish Krai. The use of fish resources that cannot be controlled can also be interpreted as a decrease in catches.

In 2017, the utilization rate decreased to 44.60% with the level of effort increasing to 115.43 %, this means that fish resources are included in the optimum catch category. In 2018, the utilization rate increased to at 100.95% that are in the condition it was overfishing and the effort level are decreased be 155.26 % is in the range of over fishing. There are four levels of utilization of fish resources, namely: low level (0 - 33.3%), medium level (33.3% - 66.6%), optimum level or catch density (66.6% - 99.9%) and the level of excess or overfishing (>100%) [11].

Based on the results of the calculation of the percentage of the level of resource utilization of Frigate Tuna (Auxis thazard) during the last 5 years has an average value of 82.33% and an effort rate of 90.31%. This shows that the condition of the level of utilization of Frigate Tuna resources has experienced a catch density or optimum. So in this case the results should be optimized by reducing the capture effort.

4. Conclusions

It is concluded that the sustainable potential (MSY) of Frigate Tuna resources from Sibolga Waters was 1,719.567244 kg/year with optimum effort \( f_{opt} \) value was 2,608.57068 trips/year. The utilization level of Frigate Tuna over the past five years has an average value of 82.33% and an effort rate of 90.31%. It showed that the condition of Frigate Tuna utilization level has been optimum. In this case, the results must be optimized by reducing the effort of catching so that the condition of Frigate Tuna remain sustainable.

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