Maximum sustainable potential and utilization rates of Goldstripe sardinella (*Sardinella gibbosa*) in Belawan Oceanic Fishing Port

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Abstract. Belawan Oceanic Fishing Port is one of the bases of capture fisheries activities in North Sumatera which has considerable fishery potential. The most dominant fish caught in Belawan is Goldstripe sardinella (*Sardinella gibbosa*). Large-scale fishing activities are considered to be able to reduce the population of *S. gibbosa* in Belawan, mainly if fishing is carried out at any time. This study aims to analyse the utilization rates and sustainable potential of *S. gibbosa* at Belawan. This research was conducted by using surplus method production from May to June 2019. The annual catch, effort data, and fishing gear of *S. gibbosa* were analysed to estimate the Maximum Sustainable Yield (MSY). The main fisheries operating in catching *S. gibbosa* include trawl, fishing line, and gillnet. The Maximum Sustainable Yield (MSY) based on the Schaefer model obtained a value of 1821.92 and 1030.87 for on the fox model; the optimum effort based on the Schaefer model obtained a value 22.76 and 23.24 on the fox model. Based on these results, we concluded that the production of *S. gibbosa* at Belawan PPS has overfishing in 2014 with a production of 2085 tons and total 47 fishing trip.

1. Introduction

One of the bases of capture fisheries activities in North Sumatera that has considerable fishery potential is the Belawan Oceanic Fishing Port, where the fishing ground is in the Malacca Strait. According to [1], Goldstripe sardinella (*Sardinella gibbosa*) is a pelagic fish in coastal waters and often found clustered over large areas. Intensive use of fisheries resources requires a good management effort. As a result of high consumer demand in the fish market, fishermen are carrying out large-scale fishing. Large-scale fishing activities is thought to reduce the populations of Goldstripe sardinella (*Gibbosa*) in Belawan waters, mainly if fishing activities carried out at any time.

For this reason, this research was aimed to estimate the maximum sustainable potential and utilization rate of Goldstripe sardinella (*S. gibbosa*) resources in the Belawan Oceanic Fishing Port as
information for fishing activities especially for Goldstripe sardinella (S. Gibbosa) in Belawan waters, so that we can avoid over-exploitation or overfishing and protect Goldstripe sardinella (S. Gibbosa) population.

2. Materials and method

2.1. Study site and sample collection
This research was conducted from May to June 2019 at the Belawan Oceanic Fishing Port, Jalan Gabion Number 20 Medan Belawan. We use a surplus production method [2], and the time series catch, effort and fishing gear of Goldstripe sardinella (S. gibbosa) taken from 2014 to 2018. The primary data were analysed to estimate the Maximum Sustainable Yield (MSY) and F-Opt (Maximum Effort) using Microsoft Excel 2013 program, and the secondary data obtained through various book references and the results of interviews about Goldstripe sardinella (S. gibbosa) at Belawan.

2.2. Catch per unit effort
CPUE estimated by using a formula [3]:

\[
CPUE = \frac{C_i}{f_i}
\]  

Where:
CPUE = Catch per Unit Effort
C_i = Catches to i-year (ton)
f_i = Effort of a fishing trip in the i-year (trip)

Then the data is processed through the Schaefer model approaches. This model is a regression analysis model of CPUE (Catch per Unit Effort) to the number of effort [4].

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

\[
C = af + b(f)^2
\]  

The Optimum Effort Value (F_{opt}) is:

\[
F_{opt} = -\left(\frac{a}{2b}\right)
\]  

The Maximum Sustainable Yield (MSY) is:

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

Where:
C = Catch per unit effort (ton/trip)
a = Intercept
b = Slope
f = fishing effort (trip) in i-period
F_{opt} = optimal fishing effort (trip)
MSY = maximum sustainable yield (ton/year)

2.3. The utilization rate and effort
The utilization rate estimated by using [5]:

\[ TP_c = \frac{C_i}{MSY} \times 100\% \quad (5) \]

Where:
TPc = Utilization rate in the i-year (%)
Ci = fish catch in the i-year (ton)
MSY = Maximum Sustainable Yield (ton)

2.4. Total Allowable catches (TAC)
The formula for the Total Allowable catches (TAC) [6] are:

\[ TAC = 80\% \times MSY \quad (6) \]

Where:
TAC = number of total allowable catches (ton/yr)
MSY = Maximum Sustainable Yield (tons)

3. Results and discussions

3.1. Production of Goldstripe sardinella (S. gibbosa)
The potential resources of Goldstripe sardinella (Sardinella gibbosa) was estimate using production data and fishing effort in the period of 2014 to 2018. The data was collected from Belawan Oceanic Fishing Port, Medan Belawan, Sumatera Utara.

![Production of S.Gibbosa Resources](image)

**Figure 1.** The production of Goldstripe sardinella (*S. gibbosa*) at the Belawan Oceanic Fishing Port in 2014 to 2018
Based on research results on the production of Goldstripe sardinella (*S. gibbosa*), production of Goldstripe sardinella in 2014-2018 dominated by purse seine accounted the highest production in 2014 (2,085 tons) and the lowest production in 2018 (416.65 tons). Fluctuation that tend to decrease in catches are caused by several factors including the presence of fish, it is known that Goldstripe sardinella fish is a type of small pelagic fish that likes to migrate to find waters which suitable for their habitat. The number of fishing effort, the higher of fishing effort can be reducing the fish production faster. Prohibition of fishing gear, since 2014 the central and regional government in Indonesia prohibiting cantrang fishing gear as well as at the Belawan Oceanic Fishing Port, its caused a significant decline for production of Goldstripe sardinella in 2015.

3.2. Fishing effort
Each fishing gear has a fluctuates the number of effort each year. Based on the number of effort in three types of the fishing gear (*purse seine*, *gillnet* and *fishing lines*), *purse seine* had the highest effort in 2015 with 6613 trips, while the lowest effort was in 2015 with 3 trip using *gillnet*. This is consistent with [8] that fishing activities in the Belawan area classified as a high one. *Purse seine* was the primary fishery at Belawan because that is one of the productive fishery.

According to fishermen who are work at the Belawan Oceanic Fishing Port, the reduction of fishermen who use *gillnet* caused by the ineffectiveness of the fishing gear, which is the fishermen cannot reach the further fishing ground by using gillnet. Fishermen prefer using *purse seine* fishing gear to reach the fishing ground. [7] states that currently, *purse seine* fishing gear has become one of the fishing gear that develops in pelagic fishing on a large scale and can be used in the waters far from the coastline. *Purse seine* fishing gear is a more effective fishing gear to catch small pelagic fish around the surface of the water.

![Fishing Effort of Goldstripe sardinella (S. gibbosa) in each fishing gear at the Belawan Oceanic Fishing Port in 2014 to 2018](image)

Figure 2. Fishing Effort of *S. Gibbosa*

3.3. Catch per unit effort (CPUE) of *S.gibbosa*
The highest CPUE value was found in 2015 is 203.333 tons/trip with the total catch of Goldstripe sardinella (*S. gibbosa*) was 610 tons and an effort of catching was 3 trips. The lowest CPUE value was found in 2017 (11,381 tons/trip) with the number of catches of Goldstripe sardinella (*S. gibbosa*) was 478 tons and an effort of catching was 42 trips. Fluctuations in CPUE value are influenced by the number of effort done by fishermen. The higher of the effort, the lower of the catches, and the value of CPUE will also decrease (Table 1).
Table 1. Estimation of Sustainable Potential of Goldstripe sardinella (S. gibbosa) using the Production Surplus Method

| Year | Production (ton) | Catch Effort (trip) | CPUE (ton/trip) |
|------|-----------------|---------------------|-----------------|
| 2014 | 2085            | 47                  | 44.3617         |
| 2015 | 610.1           | 3                   | 203.33          |
| 2016 | 627             | 25                  | 25.08           |
| 2017 | 478             | 42                  | 11,381          |
| 2018 | 551             | 23                  | 23,9565         |

3.4. Estimation of sustainable potential and optimum effort

The result of a linear regression between effort and the CPUE of the Goldstripe sardinella (S. gibbosa) using the Schaefer model (Figure 3) showed that the value of a constant (a) was 160.086 and the coefficient of regression (b) was -3.516. The estimation of sustainable potential (MSY) of Goldstripe sardinella (S. gibbosa) was 1821.92 tons/year and the optimum effort was 22.761 trips/year. Based on regression analysis, the coefficient of determination (R²) for Schaefer model was 0.58607.

Table 2. The maximum sustainable potential of Goldstripe sardinella using Schaefer and Fox models

| Value             | Schaefer       | Unit        |
|-------------------|----------------|-------------|
| a                 | 160,08622      | -           |
| b                 | -3,516563487   | -           |
| MSY               | 1821.92        | ton/year    |
| F is optimum      | 22.7617414     | trip/year   |
| R²                | 0.58607        | -           |

The maximum sustainable yield (MSY) for Goldstripe sardinella (S. gibbosa) at the Belawan Oceanic Fishing Port are 1,821.92 tons/year (Figure 5), while the optimum effort (f_opt) is 22.76 trips/year. This
value can be indicated that if the effort carried out exceeds the optimum effort, it will reduce the value of production. [10] state that if the fishing effort exceeds the optimum effort, it is should carry out a limitation of fishing effort and there should be no additional fishing effort for fishing activities in that is area.

![Figure 4. Maximum Sustainable Yield/MSY and optimum effort of Goldstripe sardinella (S. gibbosa) (Schaefer model)](image)

**Table 3.** The condition of sustainable potential of Goldstripe sardinella (S. gibbosa) at the Belawan Oceanic Fishing Port in the period of 2014 to 2018

| Year | Production (tons) | Maximum Sustainable Yield / MSY | TAC (Catches allowed) |
|------|-------------------|--------------------------------|-----------------------|
| 2014 | 2085              | 1821.92 tons/year               | 1457.53 tons/year     |
| 2015 | 610.1             |                                 |                       |
| 2016 | 627               |                                 |                       |
| 2017 | 478               |                                 |                       |
| 2018 | 551               |                                 |                       |

This study indicates that in 2015, the fishing effort still below the optimum effort with a production value is 610.1 tons/year and fishing effort are 3 trips/year. It classified to the under fishing condition. The highest production and fishing effort found in 2014 with 2085 tons/year and 47 trips/year, this value means that the overfishing has occurred, its cause at the time the government had not prohibited cantrang fishing gear. Cantrang fishing gear is included in the trawl group and its activities can damage the marine ecosystem widely. In 2018 the production of Goldstripe sardinella fish (S.gibbosa) is still under the TAC was 551 tons, its means that potential of Goldstripe sardinella fish (S.gibbosa) resources in the fishing ground around Belawan can be responsible exploitation. Based on the sustainable potential of Goldstripe sardinella (S.}
gibbosa), the total allowable catch (TAC) is 1457.53 tons/year (Table 2). This shows that fishing can still be increased to get more optimal results, but does not exceed the limit of sustainable potential or MSY that has determined that is 1821.92 tons/year. This is following [11] that the TAC can determine by analysing the production surplus. TAC is usually calculated based on the value of MSY from a fishery resource and the calculation is obtained from 80% of maximum sustainable potential.

3.5. Estimation of utilization rate

Based on the analysis, the utilization rates of Goldstripe sardinella (S. gibbosa) in 2014 was 114.43%, and effort was 206.48%, its means that the overfishing has occurred (Table 4). This shows that the level of effort has exceeded 100% so that the level of over-utilization or overfishing has occurred which can lead to the extinction of the Goldstripe sardinella (S. gibbosa) population.

Table 4. Utilization rate of Goldstripe sardinella (S. gibbosa) at the Belawan Oceanic Fishing Port in the period of 2014 to 2018.

| Year | Utilization Rate (%) |
|------|----------------------|
| 2014 | 114.44 |
| 2015 | 33.48 |
| 2016 | 34.41 |
| 2017 | 26.24 |
| 2018 | 30.30 |
| Average | 47.77% |

Based on the calculation of the percentage of utilization of S. gibbosa over the past 5 years an average value of 47.77% was obtained. This shows that the level of utilization of S. gibbosa in Belawan Oceanic Fishing Port is still in the medium range and has not been overfishing, so it is still possible to optimize catches through additional effort. This is in line with [12] who divides the utilization rate into four levels, there are low level (0 - 33.3%), medium level (33.3% - 66.6%), optimum level (66, 6% - 99.9%) and the last level are overfishing (> 100%).

4. Conclusions

Based on the estimation of sustainable potential using the Schaefer model, the maximum sustainable yield (MSY) of Goldstripe sardinella (Sardinella gibbosa) at Belawan Oceanic Fishing Port was 1821.92 tons/year, and optimum effort was 22.76 trip/year. The average utilization rates of Goldstripe sardinella (Sardinella gibbosa) until 2018 was 47.77%. This study indicates that the utilization rate of Goldstripe sardinella (S. gibbosa) in Belawan waters is still in the moderate level and there has not been overfishing.

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