Application of Schaefer model on mackerels fishery in Aceh waters, Indonesia

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Abstract. The mackerels were grouped into pelagic fish associated with oceanic habitat. Its exploitation in Aceh waters is quite intensive but not yet information related to its stock status. This information is needed in taking action on fisheries management with a quota approach. This study aims to assess of monthly production of mackerels tuna and maximum sustainable yield. This study deal with the estimation of catch and effort at maximum sustainable yield (MSY) of mackerels based on catch per unit effort (CPUE) and production of purse seine fishery in Banda Aceh during 2013–2018. Analysis was carried out using an equilibrium approach with the Schaefer model. The result showed that the average CPUE of purse seine for mackerels is 0.556 tonnes/trip. Since 2015 to 2018, the trend of biomass continued to decline and the over-fishing applied in this period. The catch at MSY of mackerels was 1506 tonnes/year and the effort at MSY was 2517 trips/year.

1. Introduction

Aceh has a lot of potential in fishing resources which can fulfill the food needs and has a high economic value. Fishing production that use purse seine fishing gear in Ocean Fishing Port (PPS) Kutaraja has increased from year 2013 to 2017, from 8,922 up to 12,305 tons. This raising cause the vessel to increase either from 223 units in 2013 up to 264 units in 2018 [1]. The increasing vessel units can increase the fishing capacity. Fishing capacity is the ability of a fishing effort used in fish production [2].

Mackerels tuna is a group of neritic tuna families, which the spread of this species is very widespread in various regions, mostly in the tropical and western Indo-Pacific regions [3]. The fishing effort that have done in Fishing Port of Kutaraja is not optimally utilized by fishermen. Eastern Aceh Ocean has accessed fishing capacity, as much as 37,927 to 44,396 tons/year with the optimum operation of purse seine vessel around 61 to 78 units [4]. If the fishing capacity keep increasing, fishermen is possibly face a big economic loss and fish stock will keep decreasing which can affect the food inventories. Therefore, there has to be a good management to overcome this, so an optimum productivity will accomplish. The purpose of the research is as follow review the monthly production using purse seine in 2018 and calculate the fishing capacity of purse seine in PPS Kutaraja.
2. Materials and Methods

2.1. Site and time
Sampling was carried out in Fishing Port of Kutaraja, Banda Aceh from August to December 2019 (Figure 1).

![Figure 1. Research site in the Fishing Port of Kutaraja, Banda Aceh](image)

2.2. Sampling and measurement procedures
The method used is by doing survey and field observation. Primary data collection method is by sampling probability. The data collection is based on primary data and secondary data from the past five years. Primary data is the fishing per month with the sample of 66 vessels that have the size more than 30 GT, and secondary data based on fishing of the past five years and the total fishing vessels.

2.3. Data analysis
1. Production of purse seine catches
The method used in this research is an observation based on the fishing production of fishermen that used purse seine gear. The data collection consists of type and total fishing given by UPTD Kutaraja, started from January to August 2018, meanwhile, September to December uses primary data based on questionnaire. However, the supporting data such as duration of fishing, and the fishing ground received from interview with fishermen especially the captain. Data analysis used were descriptive statistic by classification, tabulation, and interpretation of data, and presented in graphic to show the condition of fishing result so everyone can understand [5]. Another model that has been used is the Biomass Dynamic Model [6].

2. Fishing capacity of purse seine vessel
a. Calculation of the fishing capacity based on purse seine vessel
There are a lot of equipments for fishing by the fishermen, so one of it is the standard fishing gear, while the rest are the standardized equipments [7]. The standard equipment has a potential factor of catching or fishing power index (FPI) equal to one. The value of fishing potential by each equipment in each year based on the formula is [8]:

\[
CPUE_i = \frac{C_i}{F_i} \tag{1}
\]

\[
CPUE_{st} = \frac{C_s}{F_s} \tag{2}
\]
FPIst \( \frac{CPUEs}{CPUEs} = 1 \) ................................................................. (3)

FPIi \( \frac{CPUEi}{CPUEs} \) .............................................................................. (4)

For the rest of equipments use the following equation:

Effort standard = \( \Sigma FPIix\Sigma Ei \) ........................................................... (5)

where:

CPUEst = catch per unit effort standard

CPUEi = catch per unit effort i

Cs = total catch of standard fishing gear

Ci = total catch of i fishing gear

Fst = total effort of standard fishing gear

Fi = total effort of i fishing gear

FPIst = fishing power index of standard fishing gear

FPIi = fishing power index of i fishing gear

Fishing Power Index (FPI) from each equipment are averaged. Fishing Power Index (FPI) then multiplied by each equipment so the standard potential is achieved. The standardization will give the actual total production and standard total potential which will be used in the next analysis.

b. Maximum sustainable yield

The method used is the Schaefer model surplus production to see the relationship of fishing and fishing potential which analyzed by using Microsoft Excel.

The relationship is:

\[ Y = \alpha + \beta x + e \] ................................................................. (6)

Then, predicted with linear regression equation:

\[ Y = a + bx \] .............................................................................. (7)

where:

\( Y \) = CPUE in tons/units

\( X \) = Effort in ship unit

\( e \) = error

\( \alpha, \beta \) = estimator of parameter regression of value a and b

\( a \) = Intercept

\( b \) = Slope

Next, calculation of MSY can use the following formula:

\[ f_{opt} = -a/2b \] .............................................................................. (8)

\[ MSY = -a^2/4b \] .............................................................................. (9)

where:

MSY = maximum sustainable yield

\( F_{opt} \) = optimum effort

\( a \) = constant regression of CPUE

\( b \) = constant regression of effort

3. Results and Discussions

3.1. Purse seine production in 2018

The productions using purse seine in PPS Kutaraja during the research are mackerels tuna which include in the family Scombridae fish. The production of mackerels tuna in PPS Kutaraja was as much about 1,351 tons in 2018. The analysis result of mackerels tuna in PPS Kutaraja is shown in Figure 2.

Figure 2 shows the highest mackerels tuna production brought into PPS Kutaraja was as much as 239 tons in April, meanwhile, the lowest production was as much as 31 tons in December. Mackerels tuna was one of the fish that commonly caught by purse seine. Mackerels tuna production tends to
declined. The declining of mackerels tuna influenced by the low presence of phytoplankton, so the food supply was decreasing [9]. However, current is one of the factor which influence the mackerels tuna distribution especially *Euthynnus affinis* [10].

![Figure 2. The production of mackerels tuna 2018 in the Fishing Port of Kutaraja](image)

### 3.2. Fishing capacity of purse seine vessel

a. Catch per unit effort (CPUE) of mackerels tuna based on unit of purse seine

The analysis shows the purse seine fishing gear got the highest CPUE than handline, so that purse seine has became the standard equipment to catch mackerels tuna. Total catch, total effort, and catch per unit effort (CPUE) mackerels tuna shows in Table 1.

| Year | Production (tonnes) | Effort Standard (trip) | CPUE Standard (tonnes/trip) |
|------|---------------------|------------------------|----------------------------|
| 2013 | 909                 | 891                    | 1.02                       |
| 2014 | 1.262               | 2.074                  | 0.61                       |
| 2015 | 2.068               | 3.068                  | 0.67                       |
| 2016 | 1.618               | 3.517                  | 0.46                       |
| 2017 | 449                 | 3.323                  | 0.14                       |
| 2018 | 1.445               | 3.308                  | 0.44                       |
| **Total** | **7.751** | **16.181** | **3.33** |
| **Average** | **1.292** | **2.697** | **0.556** |

Table 1 shows the mackerels tuna resources keep increasing together with the increasing fishing effort. The highest mackerels tuna production was as much as 2,068 tons in 2015 with 3,061 trips of fishing effort. However, the lowest mackerels tuna happened in 2017 was as much as 449 tons with 3,323 trips of fishing effort. Every fishing gear have different ability, so there was a process of standardization of fishing effort first. Fishing gear used as the standard is purse seine, because the value of FPI is one. The CPUE relationship, total production and fishing effort using purse seine tend to fluctuate.

The lowest production of fishing was mackerels tuna. The production of mackerels tuna (Table 1) from 2013 to 2018 ranged from 900 to 2,100 tons. Mackerels tuna production was fluctuating, where the highest production occurred in 2015 accompanied by increasing fishing efforts. Started from 2015 to 2018 mackerels tuna production continued to decline, a significant declining occurred in 2017 up to 449
tons with fishing efforts 3,323 trips. On one hand, raising of CPUE shows the exploitation of fish resources developed, on the other hand, if CPUE declining means the fishing effort almost reach the overfishing if this case continued [11]. The increasing of fishing effort would not increase the production of mackerels tuna but would reduce the CPUE value [12].

b. Maximum Sustainable Yield (MSY)
1. Sustainable potential of mackerels mackerels tuna
As the result of relationship analysis of CPUE and fishing effort of mackerels tuna tend to decreased as shown in Figure 3 below:

![Figure 3. Regression plot of CPUE against standardized effort](image)

**Figure 3.** Regression plot of CPUE against standardized effort

![Figure 4. Equilibrium Schaefer curve (MSY) of mackerels tuna in the Fishing Port of Kutaraja](image)

**Figure 4.** Equilibrium Schaefer curve (MSY) of mackerels tuna in the Fishing Port of Kutaraja

Figure 3 shows the relationship between standard effort and fishing per standard effort unit obtained from regression value where Y-intercept id 1.196 and the slope is -0.00023x, with the coefficient determination 0.682. The regression shows CPUE tend to decline if the number of trip to catchmackerels tuna increase. This equation implies that when there is no effort (b = 0) then mackerels tuna stock
available will be 1.196 ton. The regression coefficient, \( b = -0.00023 \) explains that when standard effort decrease will cause an increase in CPUE. The determination of the coefficient \( R^2 = 68.2\% \) means that variation in CPUE 68.2\% is explained by the effort, and there are 31.8\% factors which have an effect on CPUE of mackerels tuna fishery as well, but they have not been analyzed in this study. Estimation of MSY and optimum effort \( (E_{MSY}) \) of mackerels tuna at PPS Kutaraja using linear Schaefer model shows that mackerels tuna \( C_{MSY} \) was 1.506 tons/year and \( E_{MSY} \) was 2.517 trips/year (Figure 4).

The MSY curve (Figure 4) mackerels tuna caught by purse seine and landed in PPS Kutaraja from 2013 to 2018 has exceeded its optimum fishing effort. However, the amount of mackerels tuna production in 2013 and 2014 was lower than the maximum sustainable yield (CMSY). Then, the production of mackerels mackerels tuna increased in 2015 by 2,068 tons and decreased in 2016 by 1,618 tons, but still exceeded the maximum sustainable yield (CMSY). The increasing amount of this production is line with the increasing in fishing efforts which shows the occurrence of overfishing, whereas in 2017 the production of mackerels mackerels tuna was greatly decreased by an amount of 449 tons and not exceeding the maximum sustainable yield (CMSY). In 2018, the number of mackerels mackerels tuna fish production increased by 1,445 tons still in stable condition due to below the maximum sustainable yield (CMSY).

Fishing efforts in 2013 and 2014 had a number of trips under their optimum efforts, while in 2015 to 2018 fishing efforts increased more than the optimum effort. As a result of the increasing fishing capacity, the fishing obtained by fishermen was fluctuating. The high fishing effort is caused by an increasing number of vessels and fishing gear, so that the fishing effort and competition among fishermen increases, and the level of mackerels mackerels tuna production also increases. The existence of mackerels mackerels tuna fish in the ocean of the South Sulawesi Makassar Strait has also experienced overfishing, where in 2007 the fishing as much as 6,139.6 tons had passed the sustainable value (MSY) of mackerels mackerels tuna by 4,069.75 tons/year [13]. However, in Buyat Bay the level of exploitation of mackerels mackerels tuna is 29.59\% of its potential, this indicates that the condition of the mackerels mackerels tuna fish in the area is still likely to be developed [14].

The estimation of sustainable potential of mackerels mackerelstuna could be concluded that the relationship between fishing efforts and sustainable maximum fishing was parabolic(quadratic function). If fishing activities were not carried out (effort = 0), production will also be zero, whereas when efforts continue to be raised to reach the optimum point of used, maximum production (MSY) will be obtained. This is because the relationship forms a quadratic curve, so every increase in the level of fishing effort will increase the fishing until it reached maximum production, then there will be a decrease in catch for each increase in the intensity of fishing to existing fisheries resources, and can achieve zero production at the maximum effort level and this will have an impact on the income of fishermen who were decreasing and the depletion of fisheries resources.

Mackerels tuna resources have experienced overfishing in different years. This is because the production exceeds the maximum sustainable production, so it has an impact on fish resources in the following year which if it continues to be overexploited. The catch production has a value below the maximum sustainable production (CMSY) amount that could be occurred because of the small intensity of fishing operations and fish resources for the year [15]. The decrease in the number of these resources is due to the utilization in previous years which exceeds its sustainable potential.

The capacity of fishing effort is very influential on the catch of purse seine. From 2015 to 2018 the capacity of fishing efforts exceeds the optimum fishing effort. If this overfishing effort can cause overfishing conditions that have an impact on fish resources which are decreasing over time with the size of the fish caught also getting smaller. The fishing ground that will be taken by fishermen will also be further away. However, besides that the operational costs of fishing will be greater than the income, because the fewer catches are obtained.

Sustainable fisheries management could be done so that it does not become an impact in the future. The steps that can be taken such as: 1) minimize social conflict due to the seizure of fishing areas; 2) reduce fishing pressure on fish resources to remain sustainable; 3) Providing socialization to ship
owners, captains and other fishermen to think more realistically and modernly based on the preservation of fish resources. The role of government is needed in helping to optimize all fisheries resources that are based on sustainability so that they can make the fisheries sector a reliable and strategic sector, thus avoiding excessive exploitation of fish resources and remaining stable.

4. Conclusion
Analysis was carried out using an equilibrium approach with the Schaefer model. The result showed that the average CPUE of purse seine for mackerels is 0.556 tonnes/trip. Since 2015 to 2018, the trend of biomass continued to decline and the over-fishing applied in this period. The catch at MSY of mackerels was 1506 tonnes/year and the effort at MSY was 2517 trips/year.

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