Sustainability of pompano production in the waters of North Aceh

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Abstract. Pompano fish production from 2009 to 2018 often fluctuated with the tendency to decrease in the last two years. The highest production happened in 2006 reaching 50 tons per year while the lowest production reached 24 tons in 2013. This present study aims to analyze the status of pompano resource management in the actual condition, Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access (OA) as well as to identify the level of resource utilization of pompano fish in North Aceh waters in accordance to the allowable catch. The study found that pompano fisheries resources in the MSY regime produced 54.49 tons per year and the level of effort was 1,301 trips with the profit of Rp 468,714,567 per year. In the MEY regime the catch reached 48.22 tons with the catch effort of 860 trips and the profit gained of Rp 636,447,069 per year. The management in the MEY regime is more efficient than that in the MSY. The level of pompano resource utilization is in the status of fully exploited with a percentage value of 92%. The utilization of pompano fisheries may still be done under supervision to avoid damage to fish resources and the environment.

1. Introduction
The fisheries sector in Aceh Province increased its production every year until 2018 up to 227,059.67 tons [1]. Approximately 55% of Acehnese people depend on this sector; however, the contribution of Aceh fisheries to the GRDP has been relatively low, in which in 2015 it could only reach to 4.94 percent. One contributing factor of the decrease in fisheries performance is due to economic overfishing [2], [3].

Pompano (Caranx sp) is one of the economical fishes found in Aceh with high market value, macro extensive production volume, and high production power. Ocean Fishing Port (OFP) Kutaraja in Banda Aceh is the center of the fisheries sector in Aceh together with the largest fish landing in North Aceh [4]. Pompano fish production had experienced fluctuations from 2009 until 2018 and it tended to decline in the last two years. The lowest pompano production occurred in 2012 and 2013, gaining only 26 tons and 24 tons per year, respectively; but, it experienced the highest production in 2016, reaching up to 50 tons. However, from 2017 to 2018 there was a decline in production of up to 34 tons/year [5].

Increasing production volume and decreasing quality of available resources are very likely to affect the existence of pompano in the waters of North Aceh. The Republic of Indonesia Fisheries Management Region states if the WPPNRI-572 zone has shown the level of fully exploited status, it indicates that catch efforts may only continue through improved supervision or strict monitoring. This regulation aims to protect pompano preservation resources in the future. Unrestricted access in utilizing the resources will cause over exploitation; hence, these resources can become not efficient and have the negative impact on the environment of fisheries resources. Open access fisheries are often assumed as public.
resources in which every level of the society can manage and utilize. This assumption can lead to exploitation and cause reduction in the quality of fish resources and economic rent due to biological overfishing and economic overfishing [6].

The decline in the quality of the fishery resource availability may be influenced by the economic value. Therefore, the utilization of pompano resources needs to be well managed so that the fish supply remains sustainable and no over-exploitation. Related to this issue, analysis is needed on the bioeconomic approaches to figure out the value of the biological and economical parameters. In this study, the aims is to analyze the pompano resource management status and to identify the utilization rates according to the number of allowable catches in the waters of North Aceh.

2. Materials and methods
This study was conducted from October until February 2020 at Kutaraja Ocean Fishing Port (OFP), Banda Aceh. The primary data consisted of structure costs of the fishing effort and fishing commodity prices which were obtained from direct interviews with fishermen in the port. The secondary data were collected from Aceh Department of Marine and Fisheries (DKP), UPTD Kutaraja PPS, and BPS Banda Aceh comprising time series data including data catch of pompano in 2009-2018, the inputs used (effort), the number of trips of each fishing gear per year from 2009 to 2018 CPI, and other supporting data.

The study used the bioeconomic model based on the biological model of Schaefer [7] and economic model [8]. Pompano fishing involved purse seines and fishing tool stalling. Therefore, a standardized effort was made in the fishing gear before calculating the potential estimation of pompano resources. Purse seines as the standard fishing gear and fishing rods as the additional fishing gear were standardized.

The calculation for Maximum Sustainable Yield (MSY) used below formula [7]:

\[ h_{msy} = qKE - \left( \frac{q^2K}{r} \right) E^2 \]  

(1)

Here, \( h_{msy} \) = maximum sustainable yield production; \( r \) = intrinsic growth; \( q \) = catchability coefficient; \( K \) = carrying capacity; and \( E \) = Fishing Effort. In addition, the values of biological parameters above were calculated by the estimation model Fox Algorithm [1975] [9] and [10].

\[ x = \left( \frac{Z}{u_t} + \left( \frac{1}{\beta} \right) \right) \]  

(2)

\[ y = \left( \frac{Z}{u_{t+1}} + \left( \frac{1}{\beta} \right) \right) \]  

(3)

\[ z = \left( \frac{-a}{b} \right) - \left( \frac{E_t + E_{t+1}}{2} \right) \]  

(4)

\[ q = \left[ \prod_{t=1}^{n} \ln \left( \frac{x}{y} \right)^{1/1} \right] \]  

(5)

\[ K = \frac{\alpha}{q} \]  

(6)

\[ r = \frac{Kq^2}{\beta} \]  

(7)

The profit obtained is the difference between total revenue and the total cost used. Mathematically, it can be written as follows [12].

\[ \Pi = TR - TC \]
\[ p \cdot h - c \cdot E = p \cdot q \cdot K \cdot E \cdot \left(1 - \frac{q \cdot E}{r}\right) - c \cdot E \]  

Here, \( TR \) is total revenue (IDR), \( TC \) is total cost (IDR), \( p \) is profit (IDR), \( h \) is catch (kg), \( c \) is capture cost unity effort (IDR), and \( E \) is effort (trip). By obtaining the values of biological parameters (\( r, q \) and \( k \)) and economic parameters (\( p \) and \( c \)), the solution for managing pompano through a bioeconomic approach can be considered according to the conditions of MEY, MSY and OA. The solution for the resource management of pompano fisheries through the static optimization model approach can be seen in Table 1.

### Table 1. Regime solution for optimal management of pompano.

| Variable        | MEY                        | MSY                        | Open Access                |
|-----------------|----------------------------|----------------------------|----------------------------|
| **Biomass (x)** | \( \frac{K}{2} \left(1 + \frac{c}{p \cdot q \cdot K}\right) \) | \( \frac{K}{2} \)          | \( \frac{c}{p \cdot q} \)  |
| **Catch (h)**   | \( \frac{r \cdot K}{4} \left(1 + \frac{c}{p \cdot q \cdot K}\right) \left(1 - \frac{c}{p \cdot q \cdot K}\right) \) | \( \frac{r \cdot K}{4} \) | \( \frac{r \cdot c}{p \cdot q} \left(1 - \frac{c}{p \cdot q \cdot K}\right) \) |
| **Effort (E)**  | \( \frac{r}{2q} \left(1 - \frac{c}{p \cdot q \cdot K}\right) \) | \( \frac{r}{2q} \)          | \( \frac{r}{q} \left(1 - \frac{c}{p \cdot q \cdot K}\right) \) |
| **Economic Rent (\( \pi \))** | \( p \cdot q \cdot K \cdot E \left(1 - \frac{q \cdot E}{r}\right) - c \cdot E \) | \( \pi = p \cdot h_{M} - c \cdot E_{M} \) | \( \pi = p \cdot h_{O} - c \cdot E_{O} \) |

Source: Fauzi (2006)

### 3. Results and discussions

Pompano production which tend to decrease in the last two years had been affected by catch effort (trip) and catch season. The resulting product depends on the catch effort level and the number of fish supplies available in the fishing area [11]. The average actual production of pompano in the Waters of North Aceh showed a value of 39.94 tons, whereas the result of maximum sustainable production (MSY) was 54.49 tons. These figures are projections assuming that the actual production is not overproduction.

The actual catch effort was 639 trips/year while the maximum sustainable effort value was 1,301 trips/year indicating that the average actual effort during 2009-2018 did not exceed the limit of the effort. The sustainable yield-effort curve in Figure 1 displays that some of the actual production values are still outside the curve and some are inside the curve. However, based on the average value, the actual production in the Waters of North Aceh in 2008-2018 remained below sustainable limits and did not experience biological overfishing.

Bioeconomic analysis functions to determine the utilization of maximum sustainable level for businessmen or fishermen in using fisheries resources. The development of this business not only focuses on the ability to exploit fish resources biologically, but also on the economic parameters to identify the optimal level of the value of the benefits of fish resources that fishermen can receive. Thus, the ultimate goal is to increase the income so that the fisherman welfare can be reached. Bioeconomics was carried out in several fisheries management regimes including Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and open fisheries or Open Access (OA).
The effort level achieved in this MEY condition was quite low at 860 trips/year. The result of production was 48.22 tons/year with biomass stock ($x$) of 395.93 tons per year, and the level of rents ($\pi$) reached a maximum of Rp 636,447,069 per year as presented in Table 2. This implies that the fishing effort at the MEY level is more efficient than that at the MSY level. The resource management in the MEY regime will produce a maximum profit with the production and the level of efforts that are socially optimal [12].

Table 2. The results of bioeconomic analysis of various regimes of pompano resource management.

| Model | MEY   | MSY   | OAE   |
|-------|-------|-------|-------|
| $h$ (ton) | 48.22 | 54.49 | 48.86 |
| $E$ (trip) | 860  | 1,301 | 1,719 |
| $x$ (ton) | 395.93 | 295.64 | 200.58 |
| $\pi$ (Rp) | 636,447,069 | 468,714,567 | 0 |

MEY is a long-term balance concept that refers to the production level and well-attempt level that can maximize the economic rent from fisheries activities [13]. On the other hand, MSY management is a maximum balance of catches that can be used continuously without exceeding the available stock [14]. The utilization of pompano resources in open access conditions tends to damage the conservation of the pompano resources, an impact brought by higher fishing effort level. Then, the economic rate value of Rp 0 may happen due to the benefits that are equal to the costs incurred in a fishing effort in pompano resources.

The analysis results of the management of pompano fish resources within MEY, MSY, and OA conditions revealed that the management of pompano resources in the waters of North Aceh has not reached overfishing yet, either in terms of biological fishing or economic fishing. This is because of the fishing ($f$) in the actual condition gains 39.94 tons per year, showing the lesser value than those in MSY and MEY conditions which obtain 54.49 tons and 48.22 tons per year, respectively. The fishing efforts in the actual condition of 639 trips per year are still under the management of sustainable fishing efforts (MSY) with 1,301 trips and MEY with 860 trips per year, and the economic rate achieved is Rp 582,585,009 while in MSY condition it is Rp 636,447,069. The utilization of pompano resources in the MEY condition is considered much better because it is sustainable and can provide a higher economic rate value than that in MSY and OA conditions.
As seen in Figure 2, the balance occurred in the open access condition at point OA, causing total revenue to be equal to the total cost incurred (TR = TC); thus, the profit received in this condition was zero. This condition is commonly known as the “bioeconomic equilibrium of open access fishery”.

The maximum profit would happen at the MEY point as shown by the vertical distance between total revenue (TR) and total cost (TC) which was greater than the other. In the MEY condition, the optimal level of effort was consistent with this statement that the highest economic rate shows that the efforts made are efficient toward fishing obtained so that the maximum profit is generated [12]. The balance point in MEY was also more eco-friendly compared to the effort level in the MSY management; therefore, the profit is higher and the preservation of fish resources is better maintained [15].

**Table 3. Level of utilization of pompano resources**

| Year | Production (Ton) | TAC (80%MSY) | Utilization (%) |
|------|------------------|---------------|-----------------|
| 2009 | 47.27            | 43.59         | 108             |
| 2010 | 35.69            | 43.59         | 82              |
| 2011 | 48.87            | 43.59         | 112             |
| 2012 | 26.4             | 43.59         | 61              |
| 2013 | 24.2             | 43.59         | 56              |
| 2014 | 48.47            | 43.59         | 111             |
| 2015 | 45.35            | 43.59         | 104             |
| 2016 | 50.48            | 43.59         | 116             |
| 2017 | 38.31            | 43.59         | 88              |
| 2018 | 34.37            | 43.59         | 79              |

The level of pompano resource utilization for the past 10 years showed fluctuations. Table 3 describes that in five different years the level of utilization of pompano resources had already exceeded 100%, they were 2011 of 112%, 2014 and 2015 of 111% and 104%, consecutively, with the highest happened in 2008-2019 of 39.94 tons with the allowable fishing amount (TAC) of 43.59 tons; thus, the average pompano utilization level was 92%. This finding shows that the use of pompano fish resources in the waters of North Aceh landing on the Kutaraja OFP is still in the Fully Exploited state. The fishing efforts may only be carried out continuously under supervision because the pompano resources stock has been exploited close to the maximum sustainable value and it is not recommended to have increased utilization as this can affect the sustainability of fish resources [16, 17].
4. Conclusions
Pompano fishery resources in the waters of North Aceh produce the highest production in the MSY management regime of 54.49 tons/year with the effort of 1,301 trips/year and an economic rate of Rp 468,714,567 per year. In the MEY condition, the economic rate reaches a maximum value of Rp 636,447,069 per year with an effort of 860 trips and the production of 48.22 tons per year, whereas the OA condition gains 48.86 tons with an effort of 1,719 per year. In the actual condition, it produces 39.94 tons/year with the effort of 639 trips/year and the economic rent of Rp 582,585,009 per year. The study concludes that the pompano resources in the waters of North Aceh have not experienced overfishing. However, the level of pompano resource utilization in the waters of North Aceh signifies the status of fully exploited with an average percentage of 92%.

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