Bioeconomic analysis on coral fish in Raja Ampat Regency, West Papua Province

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Abstract. Fishery resources of Raja Ampat Regency’s waters in West Papua Province have shown a declining trend in terms of total coral fish production. In order to sustainably manage the fishery for future utilization, a baseline analysis needs to be carried out as a tool for sustainable management. This paper attempts to indicate baseline performance of fisheries from bioeconomic perspectives. Data in this study was collected from primary and secondary data. Primary data collected by using questionair for asking respondents who coastal people of Raja Ampat in 6 (six) villages, than secondary data collected should be in time series format and coming from officially office related government. Than the data resulted to be analyses using bioeconomic formula. One of important results of bioeconomic analysis is that currently there is no indication of overfishing yet in Raja Ampat waters. Total production in open access level has showen 3.97 ton per week. Effort in sole owner level (MEY) has showen 9.06 trip per week. Economic rent under sole owner regime is around Rp 43,040,425.19 per week. This condition has shown that catch per unit effort has been efficient, so that fish harvest has been better and will be followed by maximum economic rent.

Keywords: bioeconomic, coral fish, Raja Ampat

1. Introduction

Most of the Raja Ampat Regency (85%) jurisdictional area is in the form of marine waters and has around 610 islands. Most (80%) of the people work as fishermen, with major commodities for capture fisheries including Tuna (Thunnus sp.), Skipjack (Katsuwonus sp.), Mackerel (Scomberomorus sp.), Tuna (Euthynnus spp.), Grouper (Epinephelus spp.), Napoleon wrasse (Cheilinus sp.), Red snapper (Lates sp.), several other types of reef fish, also shrimp and lobster [1,2]. In addition to pelagic fish, in Raja Ampat Regency, it is also dominated by reef fishes, considering the waters in Raja Ampat Regency are the main habitat for reef fish. But lately local waters, allegedly have experienced a gradual decline in fish production which is detrimental to the community. This is due to the occurrence of environmental degradation, over-exploitation, and destructive fishing activities, which are triggered by the desire to meet the interests of the moment (current generation) or the present, so that the level of fisheries resources exploitation is carried out in such a way as to obtain the maximum benefit for the now.

Declining conditions in fisheries resources stocks have been observed in some Indonesian waters, such as in the Malacca Strait, Jakarta Bay, North Java Beach, Makassar and parts of Bali [3], as well
as allegedly occurred in the waters of Raja Ampat Regency [2]. Fundamental question in the management of fisheries resources is how to utilize resources that produce high economic benefits for users, maintaining its sustainability. So that in the management of fisheries resources contains economic and biological meanings, the optimal utilization must accommodate these two things. Therefore the bioeconomic approach must be understood by the actors involved in managing fisheries resources [4].

The concept of bioeconomics began to be developed since the early 1950's. While previously the concept of biology was introduced by Graham in 1935 in the form of a Logistics model [5], which was later developed [6], which viewed fish populations as a whole. Furthermore, the economic model was developed, based on the Schaefer model and introduced the concept of economic overfishing and open access fisheries [7]. The model, known as the Gordon-Schaefer bioeconomic model, is then widely used to analyze optimal and sustainable fisheries management patterns [8].

Knowing the bioeconomic conditions of a waters is very important, in order to fisheries resources baseline conditions and fisheries resources sustainability can be known, thus facilitating sustainable management efforts. For example, if it is known that the bioeconomic conditions of the waters of Raja Ampat Regency, especially fisheries resources capture, especially reef fish or demersal of certain species, with a limited catching fleet, will facilitate sustainable management efforts. Bioeconomic analysis is usually focused on reef fish, given the habitat of reef fishes that are in the bottom of the waters that tend to settle, do not move and swim as much as pelagic fish, so that it can guarantee the accuracy of bioeconomic analysis. So that the bio-economic analysis of reef fish in an area can be used as an indicator of fisheries resources sustainability in these waters. Furthermore, it can be known how much the utilization rate takes into account the ability of resources (aspects of biology) and economic aspects, which can be used as a basis for policies in the management of coral reefs or demersal in a sustainable manner. To answer this question, this research was conducted, which specifically aimed at analyzing the level of utilization of coral fish resources in actual, sustainable and optimal conditions in the waters of Raja Ampat Regency.

2. Materials and Methods

2.1. Research time
The study was conducted from September 2008 to September 2009 in the waters of Raja Ampat Regency, West Papua Province. Map and geographical position of Raja Ampat Regency as shown in figure 1.

The consideration of selecting research sites in the waters of Raja Ampat Regency is because the waters of Raja Ampat Regency are quite extensive waters, with most of the population working as fishermen. The condition of marine and fisheries resources is relatively good, with relatively high biodiversity and domination of small island groups in it. Then to ensure sustainable fisheries management, the Marine Protected Area (MPA) has been established in these waters.
Figure 1. Geographical Position and the Territory of Raja Ampat Regency, West Papua Province, Republic of Indonesia, source: www.rajaampatkab.go.id.
2.2. Data collection method

This research is limited only to bioeconomic analysis concerning capture fisheries resources, especially reef fish or demersal for certain species, including yellow tail fish (*Caesio spp*.), *Kuwe* (*Caranx spp*.), *Lencam* (*Lethrinus spp*.) and snapper (*Lates spp*.). These fish are demersal, which are predominantly landed by boat at the Sorong Fishing Port, which is assumed that 80% of the fish landed in Sorong Fishing Port comes from the waters of Raja Ampat Regency. The research location for sampling/respondents with purposive sampling was carried out in 6 (six) villages in the South Waigeo District, namely in Yanbekwan Village, Sawingrai Village, Yen Buba Village, Kapisawur Village, Saporkren Village, and Saonek Village, with 240 respondents who adult people, man and women and live in coastal areas of 6 (six) villages above mentioned. The data analysis used in this study that the cost structure of each fishing tool from the time series data is obtained through adjustments to the consumer price index (CPI) of the Central Papua Provincial Statistics Agency (BPS) to produce the cost of the series 1 - 104 weeks.

The data collected in this study comes from primary and secondary data. Primary data was obtained through interviews and filling out questionnaires to respondents in the 6 (six) villages mentioned above, consisting of fishermen, community leaders, fisheries business managers, local governments and tourists. Primary data used includes:

1) Data on operational costs for fishing which consists of the cost of fuel oil (diesel), oil, ice blocks/packs, consumption costs (food and cigarettes) during fishing and bait;
2) Data on the cost of maintaining a fishing vessel/fishing boat;
3) Fish price data and income per trip from the ship/boat used; and
4) The social, economic and cultural conditions of the community at the research location.

The secondary data required is time series, including data on landing of reef fish or demersal in Sorong Fishing Port and inputs used (effort), price per unit output (price of fish per kg per period), consumer price index and other supporting data. This secondary data was obtained from the service/agency/institution research related to fisheries management and research at the research location. The agencies/agencies/institutions include: the Central Bureau of Statistics, the Office of Fisheries and Marine Affairs, the Environmental Service, the Forestry Service, Development Planning Office, the Fishing Port, local and central NGOs, and other related institutions. All the secondary data collected in this study verified by data should be in time series format and coming from officially office related government and should be related to indicate baseline performance of fisheries from bioeconomic perspectives.

2.3. Data analysis methods

In the fisheries resources assessment, the most important thing to know is the estimated value of sustainable catch from fish stocks, which is ideally done for each species of fish (stock-by-stock base). To find out the estimated value of sustainable catch, it is necessary to know the productivity of fish stocks first, which is usually estimated by a quantitative model. The productivity of fish stocks is influenced by various factors, both biology, climate, and human activities that cause the decline in water quality through pollution, destruction of coastal ecosystems and the breaking of the food chain.

In this study, to analyze fish stocks, a surplus production model will be used. This model assumes fish stocks as a sum of biomass with the equation:

\[
\frac{\partial X}{\partial t} = F(X_t) - h_t
\]

(1)

Notes:
- \( F(X_t) \): natural growth rate,
- \( h_t \): catch rate.

By introducing arrests, the dynamics of fish stocks can be explicitly written as follows [4]:

\[
\frac{\partial X}{\partial t} = F(X_t) - h_t + \lambda
\]

(2)
Form Logistic: 
\[
\frac{\partial X_t}{\partial t} = rX_t \left(1 - \frac{X_t}{K}\right) - h_t
\]  
(2)

Where \( r \) is the intrinsic growth rate, \( K \) is the carrying capacity of the environment. If the fisheries resources stock begins to be exploited by fishermen, then the rate of exploitation of fisheries resources in a certain time unit, is assumed to be a function of effort, which is used in fishing and stock of available resources. In the functional form the relationship can be written as follows:

\[
h(t) = H(E(t), X(t))
\]  
(3)

Then it is assumed that the arrest rate is linear with respect to biomass and effort as written below:

\[
h_i = qE_iX_i
\]  
(4)

The estimation technique used is a parameter estimation technique developed previously or often known as the CPY method [9]. Then, by substituting two optimization calculations, optimal economic benefits will be obtained.

3. Results and Discussion

3.1. Estimation of biological parameters

Biological parameters are estimated using the CYP estimator model [9]. There are also parameters that are estimated to include the level of intrinsic growth (\( r \)), the carrying capacity of the aquatic environment (\( K \)) and the coefficient of capture (\( q \)). The estimation results of these three parameters are useful for determining the level of sustainable production, such as maximum sustainable yield (MSY) and maximum economic yield (MEY).

The estimation of biological parameters is carried out on the type of reef fish or demersal caught by the fleet of boats. Table 1 below presents the output of regression variables, to estimate biological parameters, using the CYP estimator model for each reef fish catch.

| REGRESSION PARAMETER | COEFFICIENT | STANDARD ERROR | t START | F | R² |
|----------------------|-------------|----------------|---------|---|----|
| \( B_0 \)            | -0.62038092 | 0.20556382      | -3.01790|   |    |
| \( B_1 \)            | 0.68508969  | 0.06856330      | 9.99208 | 61.448641 | 0.5513629 |
| \( B_2 \)            | -0.00250380 | 0.00132545      | -1.88900|   |    |

Source: processed data

The data in table 1 above are then processed to estimate biological parameters, from each fisheries resources of reef fish or demersal with a fleet of boats. Table 2 below shows the results of the biological parameter estimation from fisheries resources, based on CYP estimator and Logistic growth function.

| BIOLOGICAL PARAMETERS | VALUE |
|-----------------------|-------|
| Natural Growth Rate (\( r \)) | 0.63140 |
| Captures Capability Coefficient (\( q \)) | 0.00659 |
| Waters Carrying Capacity (\( K \)) | 41.66624 |

Source: processed data
3.2. Estimation of economic parameters

Data for estimating economic parameters consists of the structure of costs and prices. This cost and price structure is a cross section and time series data obtained through interviews in the field. Cost is an important factor in capture fisheries business, because the amount of costs will affect the efficiency of the business.

The cost data in this study is the cost per unit effort, therefore the cost is predicted from the primary data obtained in the field. Cost per trip is very much determined by the length of the trip to sea, and the type of fishing gear per trip. In addition to the cost factor, it is also very important that the price factor or the value of the resources utilized, in analyzing the bioeconomics of these resources. Price variables affect the amount of income earned in fishing business. Nominal price data is the average value of each target species of fishing gear. Prices of these types of fish are presented in the form of fish prices per tonne, which are obtained from primary data in the field, after adjusting to the CPI from the Statistical Bureau Office of West Papua Province.

| ECONOMIC PARAMETERS | FISHERIES RESOURCES VALUE |
|---------------------|---------------------------|
| Price (Rp)          | 9,850,000/ton             |
| Cost (Rp)           | 500,000/trip              |

Source: processed data

Sustainable production is the relationship between catches and fishing efforts in a quadratic form, where the level of effort or catch that is obtained will not threaten the sustainability of fisheries resources. Sustainable production in this study is divided into two, namely maximum sustainable production (MSY) and maximum economically sustainable production (MEY). In the MSY estimation analysis, the variables used are only biological parameters, whereas in MEY analysis, the variables used are not only biological variables, but also must use several economic parameters. Biological parameters used in calculating MSY include parameters r, q, K, while the parameters used to calculate MEY include added economic parameters such as c (cost per unit effort), real price, and annual continuous discount rate.

Maximum sustainable production (MSY) in this case is calculated using the Logistic growth function. Before estimating MSY, an estimation of biological parameters must first be carried out. Furthermore, it is used to estimate the level of effort (effort, E) in the MSY condition using the \[10\], where the optimal effort level in the MSY condition is directly proportional to half of the intrinsic growth rate (r) and inversely proportional to the capture power coefficient of the tool used. This level of effort (E) is then used to estimate the optimal (x) biomass level, at the MSY level.

3.3. The Management regime of reef fish or demersal fish resources

Bioeconomic analysis is carried out to determine the maximum level of mastery for perpetrators of fish resources utilization. The development of fisheries business is not only determined from the ability to exploit fish resources biologically, but economic factors play an important role, including the factors of cost and price of fish. Biological and economic analysis approach is one alternative that can be applied in an effort to optimize fish resources mastery in a sustainable manner. By including economic factors, it will be possible to find out the optimal level of benefit value or rent from fish resources utilization received by fishermen. Because of the utilization of fish resources the ultimate goal is to increase the income and welfare of fishermen. Table 4 shows the results of estimation of biological and economic parameters for coral fish or demarsal fish resources.
Table 4. Results of estimation of biological and economic parameters of reef fish or demersal fish in Raja Ampat Regency.

| BIOLOGIC PARAMETERS     | FISHERIES RESOURCES VALUE |
|-------------------------|---------------------------|
| Natural Growth Rate (r)  | 0.63140                   |
| Captures Capability Coefficient (q) | 0.00659               |
| Waters Carrying Capacity (K) | 41.66624               |
| Price (Rp)               | 9,850,000/ton            |
| Cost (Rp)                | 500,000/trip             |

Source: processed data

Based on the data in Table 4 above, the estimation of some sustainable yield conditions, namely the condition of maximum sustainable yield (MSY), open access conditions (open access), and the condition of sole owner can be determined. The calculation results of each condition are summarized as table 5 below.

Table 5. Results of bioeconomic analysis in the management of reef fish or demersal fish resources in Raja Ampat Regency

| SOLE OWNER/MEY | OPEN ACCESS | MSY |
|----------------|-------------|-----|
| Biomass (x) (ton) | 24.69       | 7.70 | 20.83 |
| Production (h) (ton per week) | 6.35 | 3.97 | 6.58 |
| Effort (E) (trip per week) | 39.06 | 78.11 | 47.92 |
| Rent Value (π) (IDR per week) | 43,040,425.19437 | 0 | 40,825,341.52 |

Source: processed data

The level of effort in the condition of open access is far more than the condition of MSY and MEY which is as much as 78.11 trips per week, while for MSY there are 47.92 trips per week and MEY as much as 39.06 trips per week. At a high level of effort, it will cause large costs which in turn will have implications for the low rent received by fishermen. In the open access regime profits or rent obtained are Rp. 0 per week. This shows that the situation that occurs in the management regime of open access will refer to the following two opinions: (1) If the fishing effort used produces a situation where the total cost (TC) is higher than the total revenue (TR) the fisherman will lose acceptance and opt out of fisheries; (2) If the fishing effort used produces a condition where total revenue (TR) is higher than the total cost (TC), then the fisherman will be more interested and enter (entry) to exploit fish resources. So that only at the level of balance effort is reached, the exit and entry process does not occur. According to [11] that the balance of open access will occur if all economic rent has been depleted, so there is no incentive to enter and exit, and there is no change in the level of existing efforts.

Whereas in the sole owner condition (MEY) the profit level obtained is the highest compared to the open access and MSY management regime, which is Rp. 43,040,425.19 per week, or the MEY rent value is in maximum condition. Such conditions allow preventing misallocation of natural resources, because of the excess labor and capital needed for fisheries. This shows that at this level of production, the level of capture effort has been carried out efficiently, so that a better catch is obtained which is then followed by the acquisition of maximum profits. More specifically, it can be said that the MEY management regime looks more environmentally friendly (conservative minded) than MSY conditions.

3.3.1. Regime for management of open access fisheries resources (open access). The generally accepted concept of fishery resources ownership that is used by fishermen, which is considered a common property, is known as "common property resource". This concept is synonymous with resource management that is open to anyone who wants to use it. Open access is a condition when a
fisherman, or someone who exploits SDI, does it uncontrollably, or everyone can freely harvest the fishery resources [10].

Based on the data in table 5, that the catch effort on the open access management regime in the waters of Raja Ampat Regency is 78.11 trips per week. When compared with catching efforts in the management conditions of MSY and MEY as much as 47.92 trips per week and 39.06 trips per week, then in the management of fish resources the open access regime amounts to a lot more catches compared to MSY and MEY. Catching more economically (economic over fishing) will occur in uncontrolled (open access) fishery resources management [7].

The catch obtained from the open access management regime in Raja Ampat Regency waters is 3.97 tons per week, where the profits obtained are equal to zero (TR = TC). This condition will cause fishermen to tend to develop the number of fishing gear, as well as increase catch efforts to get more results. Of course, economically this is not efficient, because the profits obtained for the long term will be reduced or not at all gain or zero.

Circumstances that will occur in the open access management regime, that there are two opinions as follows: (1) If the fishing effort used produces a state of total cost (TC) higher than total revenue (TR), then the fisherman loses his income and will opt out (exit) from arrest efforts; (2) If the fishing effort produces a total revenue (TR) higher than the total cost (TC), then the fishermen are more interested and enter (entry) to exploit fisheries resources. At the equilibrium level, the exit and entry process does not occur again. The balance of open access occurs if all economic rent has been depleted, so there is no incentive to enter and exit, and there is no change in the level of existing efforts [11].

3.3.2. Regime of sole owner management. The calculation results obtained show that the effort on the sole owner (MEY) management regime is lower than the open access and sustainable conditions (MSY) regime, which is 39.06 trips per week. Rent obtained from the sole owner management regime, is the highest rent compared to the management of open access and MSY, which is Rp43,040,425.19 per week. Economic rent in the maximum economic yield (MEY) condition, also called rente sole owner is in maximum condition. This shows that at this level of production the level of catching effort has been carried out efficiently, so that a better catch is obtained and will be followed by the acquisition of maximum rent.

Based on the description above, the management of fisheries resources capture, especially reef fish or demersal, in the Raja Ampat Regency water area in the future, should no longer add fishing gear units. In the future, efforts can be made gradually, to reduce the number of fishing gear, in order to obtain optimal catch value with the rent obtained is also optimal. If this is not done, it will have an impact on fisheries resources sustainability in the form of overfishing, decreasing productivity and income levels of fishermen. The community will judge positively, if all efforts in managing natural resources produce an increase in income and natural resources that remain sustainable [12].

4. Conclusion

The condition of capture fisheries in the Raja Ampat Islands does not experience overfishing. The catch obtained from the open access management regime in Raja Ampat Regency waters is 3.97 tons per week, where the profits are equal to zero (TR=TC). This condition will cause fishermen to tend to develop the number of fishing gear, as well as increase catch efforts to get more results. Effort in the sole owner (MEY) management regime is lower than the open access and sustainable conditions (MSY) regime, which is 39.06 trips per week. In addition, rent obtained from the sole owner management regime, is the highest rent compared to the management of open access and MSY, which is Rp. 43,040,425.19 per week. This shows that at this level of production the level of catching effort has been carried out efficiently, so that a better catch is obtained and will be followed by the acquisition of maximum rent.
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