



Bioeconomic Analysis of Indian Scad (*Decapterus ruselli*) in the Bone bay Waters of South Sulawesi

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Abstract— The purpose of this research is to analyze the optimal level of production and the efforts to utilize Indian ScadFish in Bone Bay Waters. This research was conducted from July to September 2021. The method used was descriptive quantitative using a questionnaire tool. The sampling method used was the random sampling method with a total of 10 fishing Indian Scad business units. The data analysis used was standardizing fishing gear, estimating biological and economic parameters and estimating dynamic bioeconomic parameters.

The results showed that generally the level of utilization of Indian Scad fish in the purse seine fishing gear had fluctuatedvalue. The actual production conditions of the use of Indian Scadfish were higher when compared to the production in the Bioeconomic management regime, which is 52,543.67 tons while the maximum sustainable value recommended in the regime MSY is 62,889.11, MEY is 284,661.66 tons.

Keywords— Bioeconomics, Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY).

I. PRELIMINARY

Indian Scad is the largest contributor to the number of fish catches in South Sulawesi. Apart from being consumed by the community, this fish is also used as bait for tuna fisheries companies and is exported frozen. In the last five years, there has been a decline in the catch of Indian Scad fish in South Sulawesi due to increased exploitation of these fish (Umar et al., 2013).

The waters of Flores and Bone Bay, South Sulawesi, are one of the dominant Indian Scad fish producers (> 50%) in South Sulawesi (Fisheries Statistics, 2017). Purse seine is the dominant tool used to catch Indian Scad fish and several areas that are caught in Bone Bay waters include Bone, Sinjai and Palopo districts.

The potential area for Indian Scad fish is caught using fishing gear between the Payang and Purse Seine. The high demand for Indian Scad fish can further increase the exploitation of these fish resources. As a result, there will be a decline in population growth that continues with extinction (Sugiyono, 2015).

Stock assessment in every scientific study of fisheries is to determine the productivity of fisheries resource, the effect of fishing on resources and the impact of changing fishing patterns. Estimation of stock abundance is essential for evaluating the size of management units, and for estimating rates of exploitation caused by fishing (Gulland, 1983).

Some of the problems that occur due to the intensive use of Indian Scad fish (*Decapterus spp*) are that the catch has fluctuated every year, the fishing time is getting longer, the fishing area is getting farther away and the fishermen no longer choose their catch, for example, Indian Scad fish which is still small in size. The basis for resource management is how to utilize resources to produce high economic benefits for business actors, but their sustainability is maintained (Fauzi and Anna, 2010).

In an open-access system, every user feels entitled to exploit resources on a large scale (over-exploitation). As a result, resources are under pressure and become overfishing and eventually resource depletion occurs, while every user often engages in unfair competition for increasingly limited resources.

Biological aspects are also commonly used to evaluate fish resources, but without neglecting the economic aspects. Meanwhile, fishermen as business actors and resource users are oriented towards economic principles by prioritizing the maximum profit without paying attention to sustainability. For this reason, an analysis of the utilization rate of Catch Per Unit Effort (CPUE) is needed, the determination of the Level of Sustainable Potential, Optimal Effort, and the level of utilization of Indian Scad fish resources, where this information is very much needed in sustainable fisheries management (Sangaji, et al. 2017).

The fact shows that fishermen as business actors and resource users are oriented towards economic principles by prioritizing the maximum profit possible to meet individual needs without paying attention to sustainability. This research is focused on cases of high fishing effort so that overfishing and exploitation are indicated or a reduction in the availability of fish stocks, causing depletion of the Indian Scad fish resources in Bone Bay waters. This study aims to analyze the optimal level of production and the efforts to use the Indian Scad fish in Bone Bay Waters.

II. RESEARCH METHODS

A. Time and Place

This research was conducted for 3 months July - September 2020. The location of this research was Palopo City, Bone Regency and Sinjai Regency, Indonesia. The sample in this study was Indian Scad fish. This research was conducted in Bone Bay by taking locations in 3 (three) districts that serve as fishing bases, namely Palopo City, Bone Regency and Sinjai Regency, South Sulawesi

Province. The three locations were location points that represent the waters of Bone Bay.

B. Type of Research

This research used quantitative methods. Quantitative is the process of finding knowledge using data in the form of numbers as a means of finding information about what is the research problem (Sugiyono, 2013). This research was conducted with a survey method, namely by conducting field observations and direct interviews with respondents and using a questionnaire as a data collection tool. Then the data that had been obtained was analyzed quantitatively.

C. Sampling Method

The research method is a method used by researchers to obtain data and information on various matters relating to the problem to be studied. Population is a collection of all elements in the population where the sample is taken while the sample is a part of the population (Welhelmus, 2007).

This study used a random sampling method in which respondents or samples were randomly selected by taking the research location as a fishing base, namely TPI Pontap Palopo City, TPI Lonrae Bone Regency and TPI Lappa Sinjai Regency with 10 fishing business each, bringing a total of 30 business units as a sample. From the use of fishing gear, the 3 research locations represent the main fishing gear of Bone Bay, namely: TPI Pontap Palopo City with Bagan dominant fishing gear, TPI Lonrae Bone Regency with Purse Seine fishing gear, and TPI Lappa Sinjai Regency with dominant Purse Seine fishing gear.

D. Data Sources

Sources of data used in this study were primary and secondary data, including:

1. Primary data is data obtained directly from observations in the field. Primary data collection was carried out by structured interviews using a list of questions (questionnaire) supported by direct observation of fishermen's activities.
2. Secondary data is data obtained from books, records, and research or documents collected to support primary data. Secondary data collection was obtained from the Office of Marine Affairs and Fisheries, District Offices, Village Offices and BPS. The data collected includes geographic conditions and area administration, population conditions, fishery facilities and infrastructure, Indian Scad fishing effort data and

Indian Scad fish production data for the last 10 years (2010-2019).

E. Data Collection Techniques

The research data were obtained in the following stages:

1. Field observations to determine the general condition of the research locations.
2. Questionnaire
The questionnaire is a data collection technique by providing a set of written questions to respondents to be answered. The data taken using a questionnaire was quantitative.
3. Literature study, which was collecting data by studying documentation, reading literature or research results that are considered relevant to the research theme.

F. Data Analysis

Most of the data analysis carried out was quantitative analysis according to the model approach used, namely the dynamic bioeconomic model and the value of depreciation and degradation of Indian Scad fish with the following steps

- 1) Compiling production and effort data (input and effort) in the form of time series (time series), the data used in this study were 2010-2019 data.
- 2) Standardization of fishing gear.
- 3) Estimating biological parameters including water carrying capacity constants (K), natural growth constants (r), technological parameters (q).
- 4) Estimating economic parameters in the form of price per kg and production costs per trip.
- 5) Performing parameter estimation
- 6) Dynamic bioeconomics.
- 7) Calculating the optimal value based on a predefined formula. This step can be done using the help of Excel software to facilitate analysis and to create charts.
- 8) Calculating the depreciation and degradation value.

1. Catch per Unit Effort (CPUE)

After the production and effort data (input or effort) were arranged in a time sequence according to the type of fishing gear, the next step is to find the catch per unit effort (CPUE). According to Ghulland (1991), CPUE calculation aims to determine the abundance and utilization rate of fishery resources in

a certain water area. The CPUE value can be denoted as follows :

$$CPUE_t = \frac{Catch_1}{Effort_1}$$

$$t = 1, 2, \dots, n$$

Where :

$CPUE_t$ = catch per catch effort in year t

Catch₁ = the catch in year t

2. Standardization of fishing gear

Fishing gear standardization aimed to uniform effort different units, so it can be assumed that the effort to catch a type of fishing gear is the same as that of standard fishing gear. Standard fishing gear is based on the amount of catch obtained and the value of the fishing power index (FPI) with the input (effort/effort) of the standardized tool.

$$E_{std} = Y_{tot} / CPUE_{std}$$

Where :

E_{std} : Effort/standard fishing effort

$CPUE_{std}$: CPUE standard fishing gear

Y_{tot} : CPUE which is made the standard

3. Estimation of Biological parameters

Biological parameters include water carrying capacity constants (K), natural growth constants (r), technological parameters (q). Meanwhile, economic parameters include the cost per fishing effort (c / p), the price of Indian Scad fish per unit, the catch (p), and the discount rate. There are several approaches in estimating biological parameters, but in this study, the CYP estimation model (Clark, Yoshimoto and Pooley) is used with the approach and development of the Fox (1970) and Schunate (1977) model formulas, systematically the equation is written as follows: Clark *et al.*, (1992)

$$\ln(U_{t+1}) = \frac{2r}{(2+r)} \ln(q, K) - \frac{(2-r)}{(2+r)} \ln(U_t) - \frac{q}{(2+r)} (E_t + E_{t+1})$$

Where :

U_{t+1} = CPUE at time t+1

U_t = CPUE at time t

E_t = Effort at time t

E_{t+1} = Effort at time t+1

β_0 = regression result intercept coefficient

β_1 = coefficient X variable 1 regression results

β_2 = coefficient X variable 2 regression results

4. Estimation of Economic Parameters

Economic parameters include the estimated input costs, the estimated price of capture output and the cut rates of resources.

The cost of catching or estimating the cost of input is obtained from primary data, which is then made the yearly real fishing cost data series using the formula : (Najamuddin, 2014)

$$c = \sum c_i / n_1$$

Where :

c = Average fishing costs (IDR) per year

c_i = Catching cost per capture attempt of respondent i

n_1 = Number of respondents

The output price estimate is obtained from primary data, which is then made a data series of real sales prices in the year using the formula:

(Clark *et al.*, 1992)

$$p = \sum p_i / n_2$$

Where:

p = Average catch price per kg

p_i = Average price during the i season

n_2 = Number of seasons (peak, regular, famine)

The cut-off rate parameter (d) uses the equation (Clark, 1985) :

$$d = \ln(1+i)$$

Where :

i = investment interest rate – inflation rate

d = resource cut rate

5. Dynamic Bioeconomic Analysis

The output of the bioeconomic model includes optimal stock (X^*), optimal catch (Y^*) and optimal fishing effort (E^*) which are estimated using the equation, (Najamuddin, 2014):

$$X^* = K/4[c/q\phi K + 1 - \sigma/r] + [(c/q\phi K + 1 - \sigma/r)^2 + 8c\sigma/q\phi K r]^{1/2}$$

$$Y^* = rX^* (1 - X^*/K)$$

$$E^* = Y^*/qX^*$$

Where :

K : Environmental carrying capacity

c : Operating costs for catching the Indian Scad fish

p : the price of Indian Scad fish per kilogram

r : fish growth rate

q : catching power coefficient and Indian Scad fishing gear

σ : resource cut rate

As a comparison, the MSY, MEY and Open Access potentials were calculated. The calculation of the Maximum Sustainable Yield (MSY) model uses the following equation:

$$E_{MSY} = \frac{r}{2q}$$

$$Y_{MSY} = \frac{Kr}{4}$$

$$X_{MSY} = \frac{K}{2}$$

Where :

E_{MSY} : Efforts to catch MSY's condition

Y_{MSY} : The catch in MSY condition

X_{MSY} : Estimating optimal stock of MSY conditions

With the assumption that the demand curve is perfectly elastic, the fishery resource rent based on the Maximum Economic Yield (MEY) value is obtained using the following equation:

$$E_{MEY} = \frac{r}{2q} \left(1 - \frac{c}{pqK}\right)$$

$$Y_{MEY} = \frac{rK}{4} \left(1 + \frac{c}{pqK}\right) \left(1 - \frac{c}{pqK}\right)$$

$$X_{MEY} = \frac{K}{2} \left(1 + \frac{c}{pqK}\right)$$

Where :

E_{MEY} : Efforts to catch MEY's condition

Y_{MEY} : The catch in MEY conditions

X_{MEY} : Estimating optimal stock of MEY conditions

III. RESULTS AND DISCUSSION

A. Graph of CPUE value development for Indian Scad fish in Gulf Waters 2010-2019

Can be seen in Fig 3.1

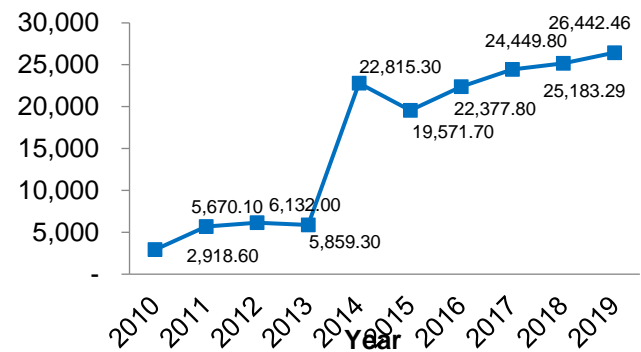


Fig.3.1: CPUE Development of Indian Scad fish Resources in the Waters of Bone Bay, South Sulawesi Province

In Figure 4.1, it can be seen that the development of the CPUE of Indian Scad fish resources in the waters of the Bay of Bone from year to year tends to fluidize or there was a tendency for a fluctuation pattern. A significant increase occurred from 2013 to 2014 and decreased in 2015. According to Alamsyah (2012), one of the characteristics of overfishing is the fluctuating or erratic fishing chart in time units and decreased production. This meant that the decrease in CPUE also indicated that the fish resource was overfishing.

B. Relationship Catch per Unit Effort (CPUE) and Effort

The relationship between Catch per Unit Effort (CPUE) and Effort can be described through the graph and the equation of the trendline, namely $y = \alpha + \beta x$. The relationship between CPUE and Indian Scad fish Effort in this study can be seen in

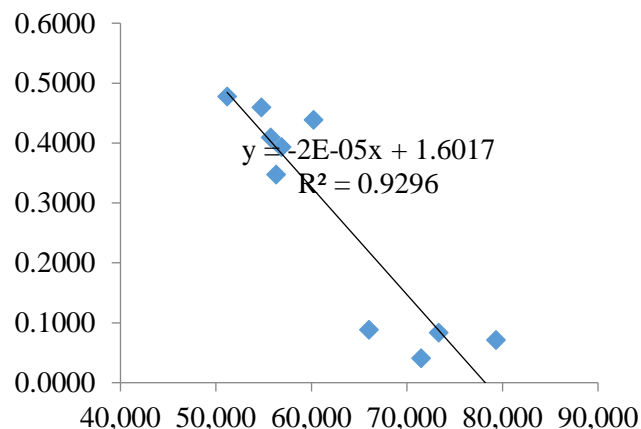


Fig.3.2: Relationship between CPUE and Effort for Indian Scad fish in Bone Bay Waters, 2010-2019.

In Figure 4.12, it can be seen that the relationship between CPUE and Indian Scad fish Effort is in the equation $y = -2E-05x + 1.6017$, from this equation the intercept value (α) is 1.6017 and the slope (β) value is $-0.00002x$. From this equation, it can be seen that the relationship between CPUE and Effort showed a negative relationship, Anna (2010) says that a negative relationship is a relationship when an increase in a variable will cause a decrease in another variable and vice versa an increase in one variable will cause a decrease in other variables. This meant that an increase in fishing activity (effort) would decrease the productivity of the catch (CPUE). The coefficient of determination (R^2) is 0.993 or 99.3%. This meant that the variation or rise and fall of CPUE by 99.3% was due to the

rise and fall of the effort value, while the remaining 0.7% was caused by other variables not discussed in the model.

C. Estimation of Biological Parameters

From the value obtained, it was then entered into the biological parameter equation so that the constant rate of fish growth, fishing coefficient and constant water carrying capacity can be estimated.

The estimation results of the three parameters presented in table 2 were useful for determining the level of sustainable productions such as maximum sustainable yield (MSY), maximum economic yield (MEY). These values can be seen in table 2.

Table 2. Estimation Result of Indian Scad fish Biological Parameters

No	Biological Parameters	Estimation Results	Unit
	Rate Constant		
1	Natural growth of fish (r)	0.53533	ton per tahun
2	Fishing coefficient (q)	0.75124	ton per unit
3	Water carrying capacity constant (K)	330.64575	ton per year

Source: Data from analysis, processed in 2021

Biological parameters were one of the factors that greatly affected the continuity of life, especially the Indian Scad fish. Because if one of the variables of the biological parameters, for example, the carrying capacity of the environment, was not following the needs, this would have an impact on the growth rate of the Indian Scad fish.

Based on the data obtained as presented in Table 2. The constant rate of fish growth (r) was 0.54 which means that the fish would grow naturally without any disturbance from natural phenomena with a coefficient of 0.54 tonnes per year.

The catch coefficient (q) was 0.7512, the catching ability coefficient value was influenced by the number of fishing gears available and the availability of the Indian Scad fish.

The constant carrying capacity of waters (K) was 330.6458, this indicated that the aquatic environment supports the production of Indian Scad fish by 330.6458 tons per year from its biological aspects, including food abundance, population growth and fish size.

D. Estimation of Economic Parameters

1. Estimated Input Costs

The costs of using the Indian Scad fish in the waters of Bone Bay consisted of fixed costs and variable costs. Fixed costs were costs that were not used up in one fishing operation (trip). Fixed costs consisted of depreciation costs for fishing tools such as boats, Purse Seine fishing tools, machines and other supporter tools. Meanwhile, variable costs were costs that were used up for one capture (Trip).

The economic theory of fisheries states that in open access fisheries where fishing costs are assumed to be proportional to fishing effort, the business will continue to increase even though the income per business unit decreases and ultimately the income will decrease until it is equal to the costs incurred (Gordon in Kar and Chakraborty, 2011).

The cost of catching or estimating the cost of input is obtained from primary data which is then generated for cost data series its annual real catch by the equation:

$$c = \sum c_i / n_1$$

Where :

c = Average fishing costs (IDR) per year

c_i = Catching cost per capture attempt of respondent i

n_1 = Number of respondents

The overall estimation results of the crab input costs in this study can be seen in Table 3.

Table 3. Analysis of Indian Scad fish Business in Bone Bay Waters

No	Kabupaten	Penerimaan	Total Biaya	R/C Ratio
1	Sinjai	1,596,000,000	750,558,567	2.13
2	Bone	2,300,400,000	896,953,528	2.56
3	Palopo	568,200,000	327,123,391	1.74

The Purse Seine Fishing Gear

Source: Data from analysis, processed in 2021

From the results of the data analysis, the value C is Rp. 65,821,182.84.

2. Estimated Output Prices

Apart from the fishing cost component required in this analysis, price component data was also needed. The price component that would be used in the analysis was the average price obtained from primary data or through direct interviews with fishermen and also secondary data from the

Fisheries Service of Sinjai Regency, Palopo Regency and Bone Regency with time series from 2010 to 2019.

One of the problems in determining prices was the existence of abnormal price movements due to the monetary crisis and the inflation rate. To overcome the abnormality of this movement, adjustments were made by converting the nominal prices obtained into real prices (Adnan, 2010).

The output price estimate was obtained from primary data, which was then made the annual real sales price data series using the formula:

$$p = \sum p_i / n_2$$

Where :

p = Average catch price per kg

p_i = Average price during the season -i

n_2 = Number of seasons (peak, regular, famine)

Table 4: Average Real Prices of Indian Scad fish in the Waters of Bone Bay, South Sulawesi Province (Rp / Kg)

No.	Season	Price
1	Musim Puncak	18,750
2	Musim Biasa	15,000
3	Musim Paceklik	12,500
	total	46,250
	p	15,417

Source: Primary data that has been processed, 2021

Based on Table 4, it can be estimated that the real price value or the p-value = IDR 15,417.

3. Estimated Discount Rate Rate (Resource Cut)

The parameter discount rate or resource discount rate refers to the investment interest rate and the inflation rate. The prevailing interest rate was 10.80 and the inflation rate was 3.58%. To get the value of the cut-rate of resources estimated by the equation, $d = \ln(1 + i)$ where i = the investment interest rate minus the inflation rate, so that the value of the resource cut rate is $d = \ln(1 + (10.80\% - 3.58\%)) = 2.10657$. $d\text{Value} = 2.10657$

E. Bioeconomic Analysis of Indian Scad fish Utilization

The bioeconomic analysis of the use of Indian Scad fish in this study was estimated into 2 (two) management regime models, namely the Maximum Sustainable Yield (MSY) management regime, the Maximum Economic Yield (MEY) management regime. The two management regime models can be determined using analytical solving tools. through the Excell program. The results of the bioeconomic optimization analysis of each Indian Scad fish management regime in this study are briefly presented

Table 5. Results of Analysis of Bioeconomic Optimization of Indian Scad fish Utilization.

Model	Effort (Unit)	Yield (Y) (Ton)	Biomass (X) (Ton)
Bioekonomi	75,191.23	52,543.67	36,547.88
MSY	126,545.56	62,889.11	125,778.23
MEY	356,295.16	284,661.66	128,619.67
Aktual	62,506.41	16,142.04	

Source: Data from analysis, processed in 2021

Production in the Bioeconomic management regime was 52,543.67, while the maximum recommended sustainability in the MSY regime was 62,889.11 tonnes, MEY was 284,661.66 tonnes. Biomass in bioeconomics was 36,547.88 tonnes while in actual conditions the production was 16,142.04 tonnes.

IV. CONCLUSION

The actual production of Indian Scad fish from the calculation results is greater than the production value based on bioeconomic calculations. This means that efforts have been made to optimize the actual catch of the Indian Scad fishing production which has reached technical efficiency and the level of Indian Scad fish in general on the purse seine fishing gear has fluctuating or fluctuating values.

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