Analysis of Yellowfin Tuna (*Thunnus Albacares*) fisheries management in the waters of North Aceh

Aprianty¹, Indra²,³ and Sofyan²

¹Student of Master Agribusiness, Universitas Syiah Kuala Banda Aceh Indonesia
²Department of Agribusiness, Universitas Syiah Kuala Banda Aceh Indonesia

E-mail: indrazainun@unsyiah.ac.id

Abstract. This study describes bioeconomic analysis of resource utilization yellowfin tuna on various management regimes through Gordon Schaefer's Model with Fox algorithm biological parameter estimation model. The purpose of this study was to analyze the biological and economic aspects of the level of utilization of yellowfin tuna resources. The study was conducted at the Kutaraja Fishing Port in Banda Aceh by survey method. The results showed the intrinsic growth (*r*) was 0.87607 tons per year, the catchability coefficient (*q*) was 0.00016 tons per year, the carrying capacity was 6.873.10 tons per year, the cost (*c*) was 17.55 million per trip (IDR) and price (*p*) is 34.94 million per ton (IDR). Based on these parameters, the management regime at the time of MSY obtained the production level (*h*) of 1.505.33 tons per year, the effort amounted to 2,771.58 trips per year and the economic rent (*π*) of 3,955.15 billion per year (IDR). In MEY conditions, the production rate (*h*) is 1,183.48 tons per year, the effort is 1,490.01 trips per year, and the economic rent (*π*) is 15,199.41 billion per year (IDR). In the condition of management of open access production (*h*) is 1,496.82 tons per year with an effort of 2,980.03 trips per year and economic rent of 0 (IDR). The static parameter analysis shows that the utilization of yellowfin tuna in North Aceh waters is economically overfishing and biological overfishing.

1. Introduction

Tuna is a large pelagic resource that has competitive market value and broad market share. Tuna of various types are exported to many regions of the world such as Malaysia, Singapore, Japan, America Europe and Australia. Tuna fishing is prime because of the world community's awareness of animal protein needs, high demand, relatively high prices, sources of employment, sources of regiona income, sources of foreign exchange, high social values, and unifying a nation because of its ability in long distance migratory so that they can cross the country [1]. The Province of Aceh has the potential to be a large exporter of Tuna to a number of countries. Based on Aceh Class SKIPM data [2], there are two exporting companies namely UD Nagata Tuna and PT Aceh Lampulo JB exporting fresh yellowfin Tuna loin to several destination countries such as Singapore, Thailand and Malaysia through Blang Bintang Aceh Besar, Sultan Iskandar Muda International Airport (SIM). This is in line with data from the Aceh Province's Marine and Fisheries Office for 2012 - 2016 [3], while the production and trips of yellowfin tuna continues increase. In 2012 the production was 2,719.9 tons, in 2013 was 3,656.2 tons and in 2016 was increased to 7,302 tons. Likewise with purse seine trips, where in 2012 there

³ To whom any correspondence should be addressed.
were 1,414 trips per year, then increased to 72,613 trips per year in 2013, in 2015 the number of trips increased to 102,592 trips per year [3]. The Kutaraja Fishing Port (PPS Kutaraja) is in Lampulo. It is the biggest fishing port in Aceh and become a central of capture fisheries in Aceh Province. Various types of fish have been landed at PPS Kutaraja, one of which is a type of yellowfin tuna. The demands of tuna exports to major countries can affect the extraction and sustainability of this species. Unlimited access to resources encourages over-exploitation and inefficient use of resources and has a negative impact on the environment. Various problems that occur in fish resources such as overfishing, overcapacity, extinction, depreciation and degradation will ultimately have an impact on the level of welfare of fisheries entrepreneurs.

Based on the description, the purpose of this study was to analyze the biological and economic aspects of the level of utilization of yellowfin tuna in the North Aceh Waters which included the production of each yellowfin tuna fishing effort, Maximum Sustainable Yield (MSY), Maximum Economic Yield (MEY), and Open Access Equilibrium (OAE), using bioeconomic analysis.

2. Methodology

2.1. Research location
This research was carried out at the Kutaraja Fishing Port in Banda Aceh. The consideration to choose the Kutaraja PPS, it is because they are the largest fishing port in North Aceh water. It can be presenting how yellowfin tuna fisheries be managed and utilized in north Aceh Waters. Another consideration was the productivity of the location, as the highest catch of yellowfin tuna was measured in North Aceh at 238 kg/DPI, followed by Indian Ocean and Sabang waters as much as 200 kg/trip [4].

2.2. Research methods
This study used a survey method. According to Ref. [5], survey research methods are used to obtain factors from existing symptoms and to seek actual information about political, social or economic institutions from a group or region.

2.3. Data collection methods
Data collection in this study consisted of primary data and secondary data. Primary data was collected through direct interviews with fishermen respondents with a prepared questionnaire. Secondary data was obtained from PPS Kutaraja, Aceh Province Marine and Fisheries Office and Banda Aceh City BPS. It consist of periodic data (time series) of catches in the years 2008-2017, fishing efforts in 2008-2017, GRDP in 2008-2017, CPI 2008-2017, and the population of Banda Aceh City 2008-2017.

2.4. Data analysis method
In analyzing the optimal management of fish resources in a region, we can analyze the bioeconomic model. There are two parameters in bioeconomic analysis, namely economic parameters which include price \((p)\), cost \((c)\), discount rate \((\delta)\), biotechnical parameters including carrying capacity \((K)\), catchability coefficient \((q)\) and intrinsic growth \((r)\).

2.4.1 Standardization of capture devices
According to Ref. [6], a catch per unit effort (CPUE) is a proportional index directly from fish stocks \((X)\) to determine the standard CPUE of the fishing gear is used as the standard chosen by fishing gear that has complete data in a time series and has the largest CPUE. The formula used is

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

where \(C_i\) is a catch result \(-i\) (kg), \(F_i\) is catch effort \(-i\) (trip) and CPUE\(_i\) is catch per unit effort (kg/trip).
2.4.2. Calculating the Fishing Power Index (FPI)

The fishing gear that is used as a standard is chosen as a fishing gear that has complete data in a cohointerest time (time series) and has the largest CPUE. Calculate FPI from each catch. The value of the capture power factor or FPI from the fishing gear that is used as a standard is 1, while the FPI from other fishing gear varies with the standard capture device being used as a comparison. Standardization of fishing gear refers to the method proposed by Guland (1983) in Ref. [7].

\[
FPI = \frac{CPUE_c}{CPUE_s}
\]

(2)

where FPI is Fishing Power Index, CPUE_c is CPUE capture device standardized (kg/trip), and CPUE_s is CPUE standard fishing gear (kg/trip). Next followed by standardization of fishing efforts calculated using the formula Guland (1983) in Ref. [7].

\[
f_f = FPI \times f_i
\]

(3)

where \(f_f\) is catching effort from standardization (trip), and \(f_i\) is catching efforts to be standardized (trip).

2.4.3. Estimated biological parameters

Value of biological parameters intrinsic growth \(r\), catchability coefficient \(q\) and carrying capacity \(K\) obtained from calculations using models of supporting estimation from the Schaefer equation [8], namely the estimation model Fox Algorithm (1970) in Ref. [9] and [10].

\[
q = \left[ \prod_{n=1}^{N} \left( \frac{x^n}{x^n} \right)^{1/n} \right] ; x = \left[ \left( \frac{x}{U_t} \right) + \left( \frac{1}{\beta} \right) \right] ; y = \left[ \left( \frac{x}{U_{11}} \right) + \left( \frac{1}{\beta} \right) \right] ; z = \left( \frac{\alpha}{\beta} \right) \left( \frac{E_t + E_{11}}{2} \right)
\]

(4)

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

2.4.4. Estimated economic parameters

To be used to determine the level of effort for maximum sustainable use economically, from a simple concept of biology above Gordon adding economic factors by including price and cost. The Gordon-Schaefer model was developed with an economic approach that aims to maximize profits. The profit obtained is the difference between total revenue and total cost used. Mathematically it can be written as follows [11].

\[
\pi = TR - TC = ph - cE
\]

(5)

\[
\pi = pqKE \left( 1 - \frac{QE}{pqK} \right) - cE
\]

(6)

where \(TR\) is total revenue (IDR), \(TC\) is total cost (IDR), \(\pi\) is profit (IDR), \(p\) is average price of fish (IDR), \(h\) is catch (kg), \(c\) is capture cost unity effort (IDR), and \(E\) is effort (trip). By obtaining the value of biological parameters \(r, q \) and \(K\) and economic parameters \(p \) and \(c\) it can be said that the solution for managing tuna fish through a bioeconomic approach, the condition of MEY, MSY and OA can be considered. The solution for the resource management of yellowfin tuna fisheries through the static optimization model approach can be seen in Table 1.

2.4.5. Fish resources dynamic model

The dynamic model concerning aspects of management which is intertemporal, these aspects bridged with the use of a discount rate. This discount rate is used to measure curinterest benefits compared to
future benefits from natural resource exploitation. Optimal management of fish resources in a dynamic context is defined as the calculation of the level of effort and optimal harvest that produces the most maximum social surplus. The social surplus in this condition is represented by economic interest from resources [11]. Regime Solutions for Optimal Management of Yellowfin Tuna Resources through Dynamic Optimization Model Approach can be seen in Table 2.

**Table 1.** Regime solution for optimal management of Yellowfin Tuna resources through the static optimization model approach.

| Variable | MEY | MSY | OPEN ACCES |
|----------|-----|-----|------------|
| Biomass (x) | $\frac{K}{2} \left( 1 + \frac{c}{p.q.K} \right)$ | $\frac{K}{2}$ | $r. \frac{c}{p.q.K}$ |
| Catch (h) | $\frac{r.K}{4} \left( 1 + \frac{c}{p.q.K} \right) \left( 1 - \frac{c}{p.q.K} \right)$ | $\frac{r.K}{4}$ | $r. \frac{c}{p.q.K}$ |
| Effort (E) | $\frac{r}{2q} \left( 1 - \frac{c}{p.q.K} \right)$ | $\frac{r}{2q}$ | $r. \left( 1 - \frac{c}{p.q.K} \right)$ |
| Economic Interest (π) | $pqKE \left( 1 - \frac{c}{p.x.K} \right)$ | $p. \frac{r.K}{4} - \frac{c}{2q}$ | $\left( \frac{p}{p.x} \right) F(x)$ |

**Table 2.** Regime solutions for optimal management of Yellowfin Tuna resources through dynamic optimization model approach.

| Variable | Formula |
|----------|---------|
| Biomass (x *) | $x^* = \frac{K}{4} \left[ \left( \frac{c}{Kpq} + \frac{1 - \delta}{r} \right) + \left( \frac{\delta + 1 - \gamma}{\delta Kpq} \right) + \frac{8c \delta}{Kpq^2} \right]$ |
| Catch (h *) | $h = \frac{x}{c} \left( pqx - c \left[ \delta - r \left( 1 - 2x \right) \right] \right)$ |
| Effort (E *) | $E^* = \frac{h^*}{q.c}$ |

Management in a dynamic optimal model is bridged by the use of *discount rates*, which in this study uses values *discount rate* based on Ramsey’s approach. According to Kula (1984) referenced in [12], values of the *real discount rate* ($r$) is defined as follows.

$$r = \rho - γg$$  \hspace{1cm} (7)

Where $r$ is *real discount rate*, $ρ$ is *pure time preference*, $γ$ is income elasticity of natural resource consumption, $g$ is economic growth and to estimate the growth rate, regression of the equation (8).

$$\ln C_t = \alpha_o - \alpha_t \cdot \ln t$$  \hspace{1cm} (8)

where $t$ is time period and $C_t$ is consumption per capita in period $t$. The *discount rate* obtained based on the results of calculations using the Kula approach is justified to produce a *real discount rate* in the form of annual continuous discount rate through the equation (9).

$$\delta = \ln(1 + r)$$  \hspace{1cm} (9)
3. Results and discussion

The Catch Per Unit Effort (CPUE) of yellowfin tuna for ten years (2008 - 2017) has fluctuated and has a tendency to increase [13]. Table 3 is the result of standardization of fishing gear on the resources of yellowfin tuna at Samudera Kutaraja Fishing Port.

Table 3. Results of standardization of catching equipment on yellowfin tuna resources in PPS Kutaraja year 2008 - 2017.

| Year | Effort (trip) | CPUE | FPI | Effort SDT | Effort SDT |
|------|---------------|------|-----|------------|------------|
|      | Purse Seine   | Hand line | Purse Seine | Hand line | Purse Seine | Hand line SDT | Effort SDT |
| 2008 | 2,910         | 144   | 0.12088 | 0.01035   | 1.08560    | 2.910         | 12.33      | 2,922.33   | 0.12088    |
| 2009 | 3,604         | 122   | 0.23637 | 0.15148   | 0.64085    | 3,604         | 78.18      | 3,682.18   | 0.23637    |
| 2010 | 3,184         | 108   | 0.17801 | 0.33722   | 1.89441    | 3,184         | 204.60     | 3,388.60   | 0.17801    |
| 2011 | 2,688         | 504   | 0.26739 | 0.22205   | 1.03641    | 2,688         | 418.54     | 3,106.54   | 0.26739    |
| 2012 | 2,606         | 690   | 0.41343 | 0.42439   | 1.02652    | 2,606         | 708.30     | 3,314.30   | 0.41343    |
| 2013 | 2,427         | 367   | 0.65029 | 0.25773   | 0.39633    | 2,427         | 145.45     | 2,572.45   | 0.65029    |
| 2014 | 2,065         | 436   | 0.53951 | 0.52113   | 0.96594    | 2,065         | 421.15     | 2,486.15   | 0.53951    |
| 2015 | 1,750         | 368   | 1.06749 | 1.10450   | 1.03467    | 1,750         | 380.76     | 2,130.76   | 1.06749    |
| 2016 | 3,510         | 982   | 0.60079 | 0.41953   | 0.69830    | 3,510         | 685.73     | 4,195.73   | 0.60079    |
| 2017 | 3,038         | 1,124 | 0.65739 | 0.26303   | 0.40011    | 3,038         | 449.72     | 3,487.72   | 0.65739    |

Based on Table 3, it can be inferred that the CPUE value is influenced by the size of the catch and the fishing effort taken. Standard CPUE calculations follow calculations with Purse Seine capture devices as standard capture devices (FPI = 1). The highest CPUE value occurred in 2015 at 1.06 tons per trip and the lowest CPUE value occurred in 2008 at 0.12 tons per trip (Figure 1).

The regression between CPUE and effort, can be seen in Figure 1, where the value of $\alpha$ is 1.0863 and $\beta$ is -0.0002. The value of $\beta$ is an indication that in each addition or reduction of one catch effort, it will reduce or increase the catch by 0.0002 tons. Therefore, the more catching attempts made, the lower the CPUE value. This shows the condition of the yellowfin tuna has experienced biological overfishing.

3.1. Biological parameter estimation

Based on the Fox Algorithm estimation model, biological parameters are obtained which include: 1) intrinsic growth ($r$), where the yellowfin tuna resources will grow naturally without any disturbance from natural phenomena or human activities of 0.87607 tons per year; 2) catchability coefficient ($q$) which indicates that each increase in fishing effort units will have an effect of 0.00016 tons per trip; and 3) carrying capacity ($K$), which shows the ability of ecosystems to support the production of yellowfin tuna resources of 6,873.10 tons per year. Estimation of biological parameters ($r$, $q$ and $K$) in
the Fox Algorithm model is useful in determining the level of sustainable production at the level of MSY. The biological parameter estimation results are presented in Table 4.

Table 4. Biological parameters of yellowfin tuna in north aceh waters.

| No | Biological Parameters     | Value   |
|----|--------------------------|---------|
| 1  | Intrinsic growth (r)     | 0.87607 |
| 2  | Catchability coefficient (q) | 0.00016 |
| 3  | Carrying capacity (K)    | 6,873.10|

3.2. Estimated economic parameters

Estimation of economic parameters using input real cost parameters and the real output price, where the real cost of input is the actual price in the field while the real output price is used CPI with the base year 2012 [14]. Based on the estimation of the amount of the average real cost of input from yellowfin tuna resources is 17.55 million per trip (IDR). The highest input costs in using yellowfin tuna in North Aceh during 2008 - 2017 occurred in 2008 amounting to 29.99 million per ton (IDR), while the lowest input costs occurred in 2014 amounting to 14.46 million per ton (IDR). The average price of real output from yellowfin tuna resources is 34.94 million per ton (IDR). In detail results of calculation of estimated input costs and real output prices of yellowfin tuna resources are shown in Table 5.

Table 5. Results of calculation of estimated input costs and real output prices of yellowfin tuna resources.

| Year | CPI Fresh Fish | Cost Rill Input (Million/trip) (IDR) | Price Rill Output (Million/Ton) (IDR) |
|------|----------------|--------------------------------------|---------------------------------------|
| 2008 | 173.80         | 29.99                                | 59.70                                 |
| 2009 | 93.01          | 16.05                                | 31.95                                 |
| 2010 | 92.91          | 16.03                                | 31.92                                 |
| 2011 | 102.43         | 17.67                                | 35.19                                 |
| 2012 | 100.00         | 17.25                                | 34.35                                 |
| 2013 | 97.55          | 16.83                                | 33.51                                 |
| 2014 | 83.79          | 14.46                                | 28.78                                 |
| 2015 | 87.45          | 15.09                                | 30.04                                 |
| 2016 | 88.60          | 15.29                                | 30.43                                 |
| 2017 | 97.48          | 16.82                                | 33.48                                 |
| Average | 101.70         | 17.55                                | 34.94                                 |

3.3. Bioeconomic analysis

Bioeconomic analysis is carried out in various fisheries management regimes namely MSY, MEY and OA. The results of the bioeconomic analysis are presented in Table 6. Maximum Sustainable Yield (MSY) is the maximum value of fishing in a region at maximum sustainable capacity yellowfin tuna resources. In Table 6, it can be seen that the biomass level of yellowfin tuna (x) in the MSY condition is 3,436.55 tons per year, the production level (h) is 1,505.33 tons per year, and the effort rate is 2,771.58 trips per year and economic rent (π) of 3,955.15 billion per year (IDR). In this MSY condition the production level is the preservation limit of yellowfin tuna fish resources and the limits of fishing efforts without interfering with the sustainability of yellowfin tuna fish resources.
Table 6. Results of bioeconomic analysis of various regimes management of yellowfin tuna resources.

| Model                  | Sole Owner/MEY | Open Access/OA | MSY       |
|------------------------|----------------|----------------|-----------|
| $x$ (tons)             | 5,025.60       | 3,178.10       | 3,436.55  |
| $h$ (tons)             | 1,183.48       | 1,496.82       | 1,505.33  |
| $E$ (trips)            | 1,490.01       | 2,980.03       | 2,771.58  |
| $\pi$ (million) (IDR) | 15,199.41      | 0.00           | 3,955.15  |

Maximum Economic Yield (MEY) is the maximum value in terms of economy in the management of fisheries resources in the hope that fishery resources within these conditions can provide economic benefits or business continuity by taking into account the sustainability of fish resources. Based on Table 6, it can be seen that the biomass level ($x$) at MEY conditions is 5,025.60 tons per year, the production level ($h$) is 1,183.48 tons per year, and the effort is 1,490.01 trips per year, and economic rent ($\pi$) in the condition of the sole owner or MEY management of 15,199.41 billion per year (IDR). In these conditions maximum production can be achieved economically and is at a level of effort that is socially optimal [11].

Under conditions of Open Access management, the biomass ($x$) level is 3,178.10 tons per year, production ($h$) is 1,496.82 tons per year with an effort of 2,980.03 trips per year and economic rent of 0 (IDR). Open Access fisheries (OA) are identical to the absence of ownership rights. Fisheries in open access conditions are open to anyone and there is no good management. In such a fishery situation, fishing efforts will continue to be increased as long as there is production until the entire economic interest is driven to zero. Comparison of the use of static optimization of yellowfin tuna resources is shown in Figure 2.

From the results of the static parameter analysis of yellowfin tuna resources in the Waters of North Aceh, it is clear they have experienced biological overfishing and economic overfishing. This can be seen from the effort of catching or effort ($E$) yellowfin tuna in the actual condition of 3,128.68 trips per year, where the effort value is higher when compared to the effort in the condition of MSY and MEY conditions. This is strongly supported by the value of profit ($\pi$) obtained in actual conditions, which is only (5,537.06 IDR) billion per year, whereas in MEY conditions the profit can reach 15,199.41 billion per year (IDR).

The total revenue from the exploitation of yellowfin tuna is obtained from the multiplication of the average price of yellowfin tuna with the catch. The total cost is the result of multiplying the catch costs per trip with the efforts made. Economic rent or profit is the difference between total revenues and the total costs incurred for a single arrest operation. The relationship of total revenue, total costs, profits and effort to various business conditions (MSY, MEY and open access) can be seen in Figure 3.
Based on Figure 3, the condition of managing open access provides a profit of 0 IDR because the value of TR = TC. In this condition there is a balance of management, or commonly known as "bioeconomic equilibrium of open access fishery".Fishermen only get opportunity costs while economic rent or profits are not obtained. In the balance of open access, the level of effort used is greater than the level of effort in the condition of MSY, so that the costs used for catching yellowfin tuna increase. The increase in fishing costs is what causes economic overfishing. This condition is also indicated by the low value of biomass because exploitation has been carried out to its lowest point. The maximum sustainable profit will be obtained at the level of effort where the vertical distance between total revenue (TR) and total cost (TC) is the largest distance (line AB). According to the economics of fisheries resources literature, this level of effort is often referred to as MEY or economic maximum production, and is an economically optimal level of effort [11]. Therefore, balancing the condition of the sole owner or maximum economic yield management looks more environmentally friendly compared to the level of effort at the equilibrium point in the management conditions of MSY, because the maximum profit is achieved with minimum efforts.

3.4. Analysis of dynamic optimization of the management of yellowfin tuna resources

The results of the analysis with a discount rate level on optimal dynamic management of yellowfin tuna resources can be seen in Table 7.

| SDI Management Model | Dynamic Optimal (i = 7, 8) | Dynamic Optimal (i = 10) | Dynamic Optimal (i = 12) | Dynamic Optimal (i = 15) | Dynamic Optimal (i = 18) | Actual |
|----------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------|
| x (tons)             | 4,397.98                  | 4,894.49                  | 4,871.09                  | 4,837.53                  | 4,805.71                  |        |
| h * (tons)           | 1,387.51                  | 1,234.40                  | 1,243.03                  | 1,255.15                  | 1,266.39                  | 1,412.99|
| E * (trips)          | 1,996.19                  | 1,595.75                  | 1,614.62                  | 1,641.69                  | 1,667.36                  | 3,128.68|
| π (million IDR)      | 23,308.88                 | 158,670.00                | 133,179.92                | 107,625.25                | 90,530.43                 | (5,537.06)|

Based on Table 7, the comparison of resource utilization of yellowfin tuna is in actual conditions and at optimal dynamic conditions. In terms of production, the actual condition is higher than the production value at optimal dynamic conditions. In actual conditions, the production value is 1,412.99 tons, while in dynamic optimal conditions with a discount rate of 7.8% of 1,387.51 tons, the discount rate of 10% is 1,234.40 tons, the discount rate of 12% is 1,243.03 tons, the discount rate of 15% is 1,641.69 tons and the discount rate of 18% is 1,641.69 tons. This condition indicates that the use of yellowfin tuna fish resources has seen economic overfishing.

At the level of effort carried out at dynamic optimum conditions the value is smaller than the level of effort in the actual condition. The same thing also happened in economic interest, where the
economic interest obtained under actual conditions was far smaller than the utilization of the natural yellowfin tuna resources at optimal dynamic conditions, in North Aceh waters has been biologically and economically overfished.

4. Conclusion
Based on the results of the analysis, it can be formulated some conclusions as follows yellowfin tuna fishery resources in North Aceh waters produce the highest output at MSY management regime which amounted to 1,505.33 tons per year, the optimal preservation effort at 2,771.58 trips per year and optimal economic rent of 3,955.15 IDR billion per year. Resource utilization yellowfin tuna (Thunnus Albacares) in North Aceh water indication have undergone more catch biological activity (biological overfishing) and economic overfishing will require optimization of resource management through the reduction effort arrest of 3,128.68 trips per year to 1,490.01 trips per year ($E_{MEY}$) so that it can obtain an optimal economic rent 15,199.41 IDR billion per year.

References
[1] Kantun W 2018 Pengelolaan Perikanan Tuna (UGM Press. Gadjah Mada University)
[2] SKIPM Kelas I Aceh 2017 Rekapitulasi Ekspor Hasil Perikanan Tahun 2017 Banda Aceh
[3] Dinas Kelautan dan Perikanan Aceh 2018 Statistik Perikanan Tangkap Provinsi Aceh 2008-2017. Banda Aceh
[4] Bahri S, Simbolon D and Mustaruddin 2017 Jurnal Teknologi Perikanan dan Kelautan 8 95-104
[5] Nazir M 2009 Metode Penelitian (Ghalia Indonesia Jakarta)
[6] Clark C W 1985 Bioeconomic Modelling and Fisheries Management (New York – Chichester – Brisbane – Toronto – Singapore : John Willey and Sons) 291
[7] Naufal A 2014 Analisis Kebijakan Pengelolaan Optimal Perikanan Cakalang di Pesisir Utara Aceh. Tesis. Sekolah Pascasarjana. Institut Pertanian Bogor. Bogor
[8] Schaefer M B 1954 Inter-American Tropical Tuna Commission Bulletin 1 (2) 23-56
[9] Sobari M P, Diniah, Isnaini 2009 Jurnal Mangrove dan Pesisir 9 (2) 56-66
[10] Zulbainarni N 2012 Teori dan Praktik Pemodelan Bioekonomi dalam Pengelolaan Perikanan Tangkap (IPB Pr. Bogor)
[11] Fauzi A 2006 Ekonomi Sumberdaya Alam dan Lingkungan (PT Gramedia Pustaka Utama. Jakarta)
[12] Anna S 2003 Model Embedded Dinamik Ekonomi Interaksi Perikanan-Pencemaran. Disertasi. Sekolah Pascasarjana. Institut Pertanian Bogor. Bogor
[13] UPTD Pelabuhan Perikanan Samudera Kutaraja 2018 Data Ikan Yang Di Daratkan di UPTD PPP Lampulo Kota Banda Aceh 2008-2018. Banda Aceh
[14] Badan Pusat Statistik Kota Banda Aceh 2018 Banda Aceh Dalam Angka 2008-2017 Banda Aceh