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Bio-Economics Analysis of Skipjack (*Katsuwonus pelamis*) Fishery on Banda Sea – Maluku Province

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Abstract

Optimum biologically and economically utilization level of fishery resources should be determined earlier in order to avoid it from over-exploitation. This issue is crucial, because currently many valuable fishery resources are extinctly in danger as a consequence of over-fishing. The objective of this research is to determine bio-economic equilibrium of Skipjack (*Katsuwonus pelamis*) resource in Banda Sea. Data were collected by interviews using questionnaire, and analyzed using Gordon-Schaefer's method combined with Fox Algoritm. The results showed that biological equilibrium (MSY) of Skipjack in Banda Sea and the waters surrounding attained at annual production capacity of 30.954,65 ton, with optimum efforts level (E_{MSY}) of 21,251 trips per annum. Meanwhile, the maximum economic yields (MEY) was attained at efforts level of 20,431 trips per annum with production size ((h_{EMY}) was 32.905,91 ton per annum. Economical equilibrium was produced at open access condition with efforts level of 40.862 trips per annum and production of 4.889.98 ton per annum. Optimum utilization of lower biological and economical pressures was at efforts level of 20.431 trips per annum and production size was 32.905,91 ton per annum.

Keywords: MEY, MSY, over-fishing, Skipjack.

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1. Introduction

Although global economic systems depend on supply from natural resources for their stock but it, sometimes, could not be used sustainably [1]. In one hand, human needs tend to be increased as the population increased which have impacts on increasing the utilization of fishery resources [2]. On the other hand, the characteristics of fishery as common property are vulnerable to over-fishing [3]. The question raised then is how many fish are maximum to catch without disturbing the existing stocks and its sustainability. Such question is important to raise and become a basis for production analysis, because failure to address the question may affect mismanagement of fishery resources [4].

In other words, it is important to maximize fishery resources utilization while maintaining its sustainability. There are two issues to be addressed, namely economical and biological issues [5]. The economical issue is related more to resource rents as triggered by resource management. Negative resource rent is caused by poor resource governance. Conversely, positive rent is produced by good resource governance [6]. Early, management of fishery resources has been emphasized on biological factor using Maximum Sustainable Yield approach (MSY) based on Schaefer model. The biological governance model was proposed by Gordon (1954) by adding price and cost as economical variables into the Schaefer model in attempting to develop Maximum Economic Yield (MEY) concept. Therefore, the model is known as Gordon-Schaefer bio-economic model [7,8,9,10,11]. MSY is a simple way for managing resources by taking it into consideration that over exploitation will result in productivity losses [12].

Maximizing fishery production bruto at MSY level may not guarantee maximum profits because it depends on the price and operational costs and therefore may zero or negative [13]. Maximum economic yield (MEY) is a concept of long term equilibrium which emphasized on production and effort level for achieving maximum profits (Dichmont, et al, 2010). Bio-economic model provides efficient estimation of resource utilization through MEY analysis. It requires significant information about price, cost and fish biological aspects. Furthermore, bio-economic model is optimization model which useful for forecasting a set of control variables, including size of armada or efforts; and for maximizing profit [13].

Skipjack is an important economical resource for Indonesian non-fuel export. It is abundantly distributed especially in eastern part of Indonesia. For instance, in Maluku province in 2010, production of skipjack was 35,852.4 ton or 4.79 percent of total fish production (Fishery and Marine Agency Maluku Province, 2011). Banda sea is the most prolific fishing ground for skipjack in Maluku Province. The main fishing gear for skipjack in Maluku is pole and line (*huhate* in local term). Besides *huhate*, there are small purse seine and trolling used by the local fishermen. Currently, large purse seine is operated by industrial fishermen for catching skipjack.

The plan of making Maluku as the national fish barn and supported by releasing National Government permit for large fishery to operate large purse seine in skipjack fishing have deteriorated skipjack resource exploitation in

Maluku. It raised critical questions of how many skipjack can be harvested without disturbing its biological and economical equilibrium; then, how many efforts are required in order to produce maximum profit? The answers will be foundations for estimating optimum utilization level of skipjack in order to attain its biological and economical equilibrium. It will be in line with the obligations stated in Code of Conduct for Responsible Fisheries *(CCRF)* which demanding the application of scientific proofs for good fishery resource governance [14]. Therefore, over-exploitation of fishery resources as a signal by [15,16] can be prohibited, especially for skipjack in Maluku. This article intends to estimate bio-economic equilibrium for skipjack resource in the Banda Sea of Maluku Province. The expectation is the valuable information that can be used as a basis for policy making in relation to sustainable utilization of skipjack resource in Maluku Province.

2. Methods

2.1 Data Collection

Data were collected from October 2011 until May 2012 in Ambon city and Central Maluku regency of Maluku Province. Two ports of skipjack storage in Maluku were selected. Production time series and number of efforts of Fishery and Marine Agency were gathered from 1990 to 2010. Pole and line, purse seine and troll line were utilized to catch skipjack (Fishery Agency Maluku, 2011). Primary data such as fish price, production cost and income from each fishing gear were collected directly from ship owner using purposive sampling. Samples collection were twelve pole and line ships, nine purse seines and twenty troll lines. Primary data collection were then selected in order to calculate average cost, price and income from each effort of each fishing gear. Incomplete ships data were withdrawn from the measurement, while complete ships data were proceeded to bio-economics analysis.

2.2 Data Analysis

2.2.1 *Catch per Unit Effort (CPUE)*

The CPUE was calculated in attempts to determine abundance and fishery resources utilization level in certain areas, after both production and efforts data tabulated for each fishing gear. Efforts in this context were fishing trips. Formula for calculating the CPUE is as follow:

$$CPUE_t = \frac{Catch_t}{Effort_t}$$

Notes :

$CPUE_t$ = fish catchment per effort in year to-t

$Catch_t$ = fish catchment in year to-*t*

$effort_t$ = effort in year to-*t*

2.2.2 Fishing Gear Standardization

Standardization of the three fishing gears for skipjack is important in attempting to calculated the inputs aggregately, because each fishing gear has different capacity. Standardization is required in order to gain total sum of total effort (Fauzi and Anna, 2005). Standard fishing gear is the fishing gear which has the highest productivity in skipjack harvesting or the one which has the largest average CPUE. The formula for fishing gear standardization to-n at period t is :

$$E_{std} = \varphi_{nt} E_{nt}$$

The value of φ_{xt} is measured by CPUE ratio of *n* fishing gear against standard fishing gear at period to-*t* as follows :

$$\varphi_{nt} = \frac{U_{nt}}{U_{std}}$$

Notes :

E_{std} = standard *Effort*

Φ_{nt} = capacity index of fishing gear *n* at period to *t*

E_{nt} = nominal effort of fishing gear *n* at period to *t*

U_{nt} = *CPUE* of fishing gear *n* at period to *t*

U_{std} = *CPUE* of standard fishing gear

2.3 Estimating biotech parameter

The value of biotech parameter such as *instrintic growth* (r), *carrying capacity* (K) and *catchability coefficient* (q) were estimated using supported Schaefer estimation model (1954), that is Fox Algoritm estimation model using Microsoft Excel as follows:

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

$$x = \left[\left(\frac{z}{U_t} \right) + \left(\frac{1}{\beta} \right) \right]$$

$$y = \left[\left(\frac{z}{U_{t+1}} \right) + \left(\frac{1}{\beta} \right) \right]$$

$$z = \left[\left(-\frac{\alpha}{\beta} \right) - \left(\frac{E_t + E_{t+1}}{2} \right) \right]$$

$$K = \frac{\alpha}{\beta} \Leftrightarrow r = \frac{Kq^2}{\beta}$$

Bio-economics Equilibrium

Bio-economics equilibrium is analyzed by using static model as shown in Table 1.

Table 1. Static Optimization Model of Different Management Regimes

Variables	Management Regimes		
	MSY	MEY	OA
Catch (h)	$\frac{rK}{4}$	$\frac{rK}{4}\left(1+\frac{c}{pqK}\right)\left(1-\frac{c}{pqK}\right)$	$\frac{rc}{pq}\left(1-\frac{c}{pqK}\right)$
Effort (E)	$\frac{r}{2q}$	$\frac{r}{2q}\left(1-\frac{c}{pqK}\right)$	$\frac{r}{q}\left(1-\frac{c}{pqK}\right)$
Economical Rents (π)	$(ph)-(cE)$	$(ph)-(cE)$	$(ph)-(cE)$

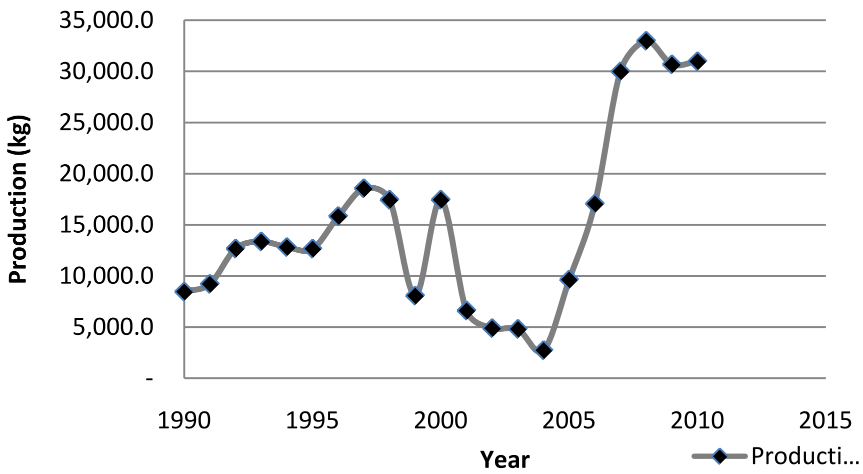
3. Result and Discussion

3.1 Catch per Unit Effort (CPUE)

Fishing gears of skipjack system in the Banda Sea are pole and line, purse seine and troll line. Average CPUE of the three fishing gears are respectively as follows: pole and line is 1 ton per effort, purse seine is 140 kg per effort and troll line is 25 kg per effort. CPUE of troll line is the lowest, because it used small ship (6 m x 65 cm x 64 cm). This small ship has narrow sailing capacity in comparising to far fishing ground. Besides, the target of using troll line is more on catching large tuna (*Thunnus albacares*) size (≥ 30 kg per individu) rather than skipjack. Skipjack was harvested as secondary product beside tuna fishes in order to match production cost and as a household consumption.

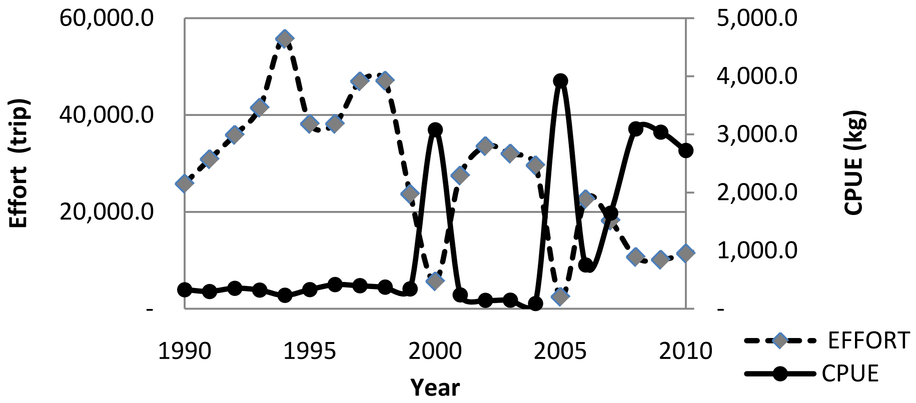
CPUE of purse seine is lower (140 kg per effort) than other fishing gears because it was used to catch the small pelagic fishes rather than skipjack. Pole and line ships are bigger (20-30 GT) and load more skipjack than others fishing gears, therefore, it is possible to produce higher CPUE (1.0 tone per effort). The average production of pole and line is consistent as reported by Krikof and Waileruny (2004) who conducted research in Galala village at Ambon Town that was 1,8375 tone per effort.

The trend of skipjack production for the first ten years (1990-1999) was increased slightly in which the highest production level was attained in 1997 (18,555.4 kg). Skipjack production for the first ten years (1990-1999) tended to increase although there was sharply decreased in 1999, when the highest production 18,555.4 kg was attained in 1997. The situation was different in 2000-2005, when it reduced significantly. In 2000-2001, the reduction was from 17,445.9 kg to 6,607.8 kg. The lowest production was 2,722.9 kg in 2005. After 2005, the trend was gradually increased to 32,989.5 kg (Picture 1).



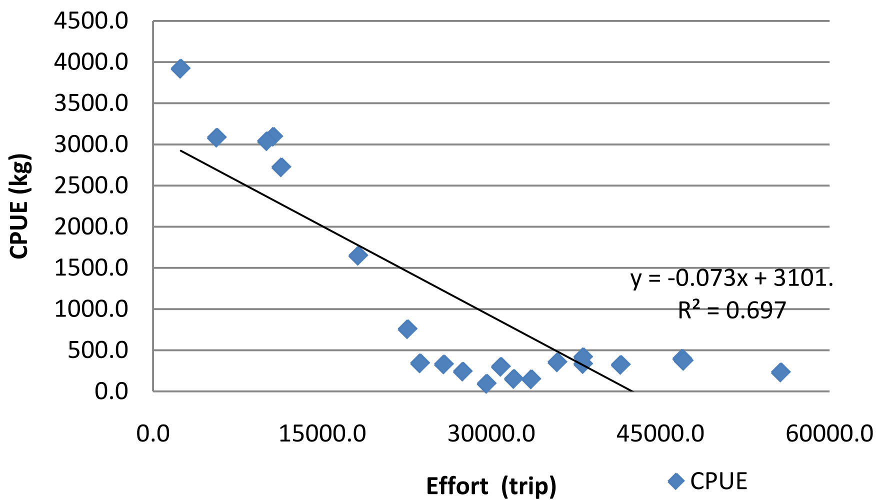
Picture 1. Production Development of Skipjack in Banda Sea and surroundings 1990-2010

Since 2000, the increasing of efforts triggered to the decreasing in skipjack production or *vice versa*. As can be seen in Picture 2, in the first ten years the increasing of efforts has not pushed the increasing of CPUE. Significantly change to be appeared during the second ten years when the increasing of efforts reduced the CPUE or *vice versa*. The lowest production with the highest CPUE attained in 2005. The result showed that high efforts applied during 1990 until 1998 affected huge pressures on skipjack resource.



Picture 2. Development of Effort and CPUE of Skipjack in the Banda Sea and the waters Surroundings of Maluku Province during 1990-2010.

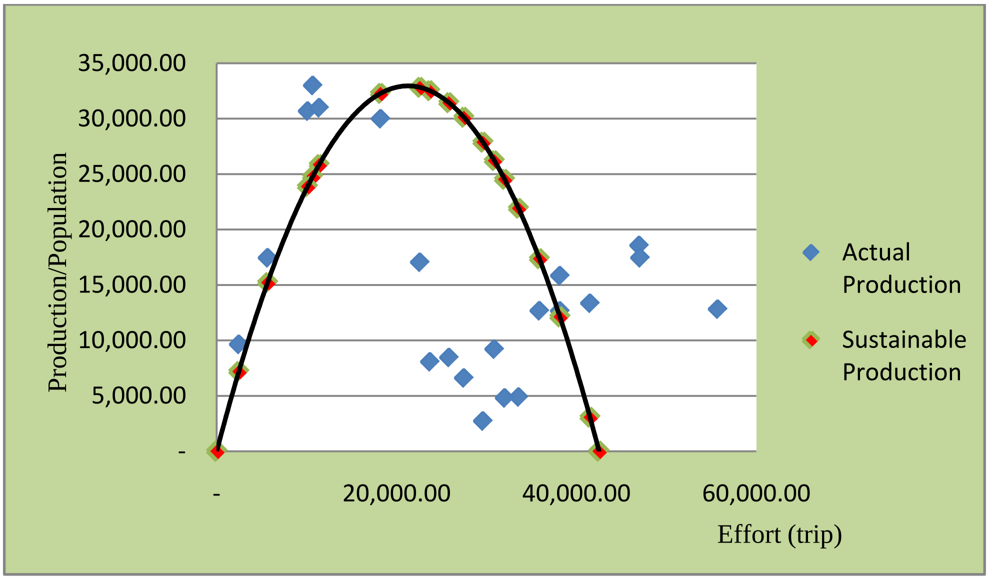
The correlation between efforts and CPUE in 1990 – 2010 showed negative growing; Y = 3101 - 0,073X, means that more efforts applied would reduce the CPUE. The results indicated that skipjack resource in the Banda Sea and the waters surrounding of Maluku Province is under catchment pressures.



Picture 3. The Correlation between Efforts and CPUE of Skipjack in the Banda Sea and the waters surrounding of Maluku Province during 1990-2010.

3.2 Bio-economy Equilibrium of Skipjack

Sustainable production of skipjack in the Banda Sea during the periods of 1990-2010 was lower than the actual production, especially in 1994, 1997 and 1998 as shown in Picture 4. The maximum of sustainable production was at the efforts of 20,000 trips with the maximum production less than 35,000 ton. The zero sustainable production was attained at efforts of 40,000 – 45,000 trips. It indicated that to produce optimum production without disturbing sustainability of skipjack resource required approximately 20,000 trips.



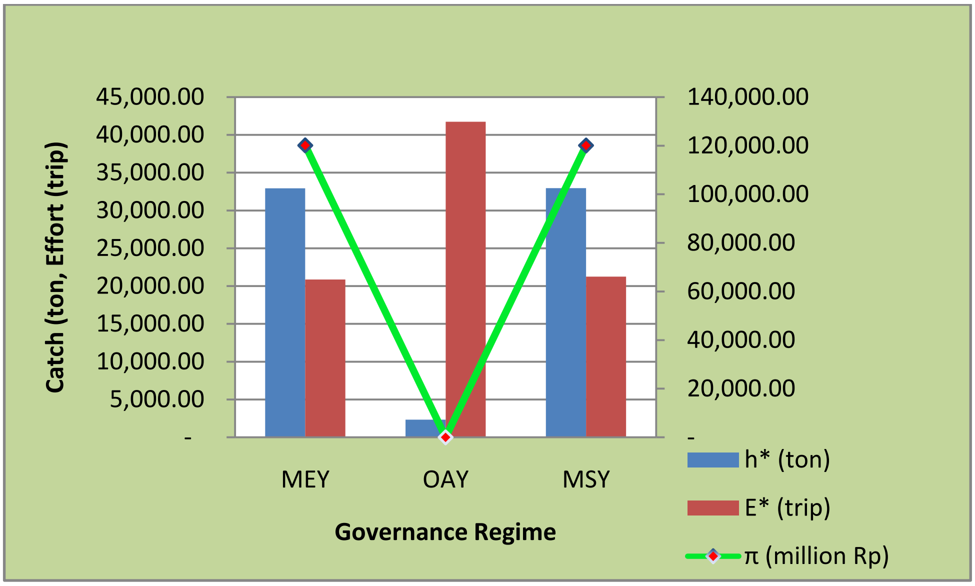
Picture 4. The distribution of Actual and Sustainable Productions of Skipjack in the Banda Sea of Maluku Province during 1990-2010

Biological and economical equilibriums which were determined by calculating the Maximum Sustainable Yield (MSY) and the Maximum Economic Yield (MEY) utilizating the open access level are noted in Table 2. The maximum biological production (h_{MSY}) was 32,954.98 ton/annum, while the maximum profit was gained at h_{MEY} 32,905.91 ton/year and the equilibrium of open access h_{OAY} was at production level of 4,889.98 ton/annum. The optimum biological efforts (E_{MSY}), the economical efforts (E_{MEY}) and the open access were 21.251 trips/annum, 20,431 trips/annum and 40,862 trips/annum, respectively. How much efforts exactly are required to produce peak MSY as analyzed next.

It was different governance regime in different bioeconomy parameter, however, the maximum production, effort and economic rents at MSY and MEY have small difference. The highest of effort was at open access management followed by MSY and the lowest was MEY governance regime, respectively. The highest production was gained at MSY. However the difference production of MSY and MEY was very narrow. The lowest production attained at open access with zero economic rent. The maximum economic rent was produced at MEY which was higher than MSY (Picture 5).

Table 2 Bioeconomy solutions for different governance regimes

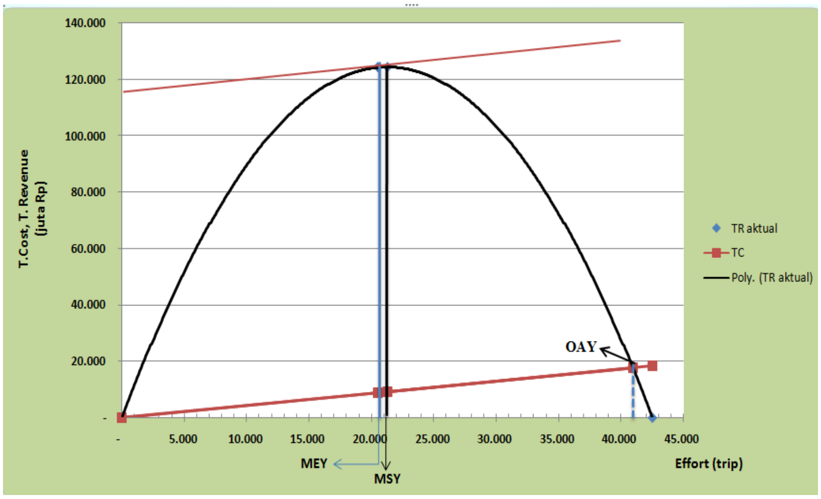
Bioeconomy	Governance regime		
Parameters	MSY	Sole Owner / MEY	Open Access/OAY
Production (h*) (ton)	32,954.98	32,905.91	4,889.98
Effort (E*) (trip)	21,251	20,431	40,862
Economic rents (π) (million Rp)	114,980.99	115,166.49	(0,00)



Picture 5. Skipjack Resource Governance Regime in Banda Sea Maluku Province.

For long time, economists have been argued that biomass is important for maximum economical profit (b_{MEY}) of fishery governance [17]. MEY is a long term equilibrium concept based on output and effort to maximize profit of fishery resource governance [14]. Fishing at MEY point will produce maximum profit for the ship owner and labor, depend on sharing benefit system [19]. If we count economic rent of fishery value chain from fishermen hand to consumers, then the actual maximum profit produced at MSY = MEY [20]. Somalia and Hanneson (2010) has contested this argument by arguing that even though economic rent for each value chain counted, however the highest economic rent are still achieved at MEY point without disturbing biological equilibrium [21].

The correlation between total revenue and cost for skipjack business in the Banda Sea is presented in Picture 6. It can be seen that the MEY point is attained at number of effort of 20,431 trips/annum with the production of 32,905.91 ton. This MEY point has very narrow range with the maximum production at MSY of 32,954.98 ton/annum and effort of 21,251 trips, due to the operation cost was lower but selling price higher. Clark (1990) as cited by Sumaila and Hannesson, 2010 explained that perhaps MSY and MEY are equal at operational cost is zero [21]. However, this narrow difference between MSY and MEY level may endanger sustainability of skipjack resource in the Banda Sea of Maluku Province if the government will not take proper governance actions.



Picture 6 . The Correlation between Total Revenue and Operational cost

Economically, the highest profit attained at the MEY level although its production level was lower than MSY level. Each effort level was below the open access equilibrium, while the total revenue was bigger than total production cost which produce more profit. The profit is the most interest aspect for the entrepreneur to enter the fishery sector [5]

The profit increased as the fishing intensities incerase. Here, maximum profit attained at effort level of 20,431 trips, that is effort at the MEY level. After MEY level achieved, the profit will reduce gradually to zero (no profit at effort level of 40,862 trips which equal to open access equilibrium). In other words, from governance perspective the utilization at MEY level are more conservative than at MSY level [22].

The promising profits from the skipjack business will attract the fisherment to expand effort or number of trips to achieve maximum profit. Such expansion will be continued to attain open access equilibrium in which the fishermen receive opportunity cost only without economical rents [5]. At open access equilibrium, total revenue is equal to the total cost (TR = TC) or the break even point. At this point, business activities will not produce profits anymore.

Bioeconomiy equilibrium at open access regime occured when certain production number produce zero profit [8]. At the condition when the effort is over open access equilibrium, then total cost will be bigger than total revenue (TC > TR), thus, the economical rent will be negative. Negative rent is produced as a result of over used of effort which also means that at that time economic overfishing has occurred [6]. Also, at this point the fishermen will suffer from loss and tend to leave the business. Therefore, open access equilibrium is an equilibrium point for the fishermen to enter the business because in such governance regime everybody has free access to the resource.

The result found that the optimum biological utilization of skipjack resource was occurred at production level of 32,954.98, whereas the highest profit was gained at production level of 32,905.91 ton/annum. Current actual average production is 15,088.265 ton which is smaller than the optimum utilization at MSY and MEY level. It means that skipjack resource utilization in Banda sea has not optimum yet. However, additional fishing gears have to have equal catch-ability to currently available. Providing higher fishing gears capability such as large purse seine may disturb biological and economical equilibrium of skipjack resource.

4. Conclusion

The profit of skipjack business in the Banda Sea increased as fishing intesities increased and attained optimum at efforts level of 20,431 trips (level of effort at MEY level). After passing through the MEY level, the profit will gradually decrease to zero at effort level of 40,862 trip (which is equal to effort at open access regime). Biological equilibrium occurred at production size of 32,954.98 ton/annum within effort level of 21,251 trips/annum. The maximum profit of the business attained at production size of 32,905.91 ton/annum and effort level of 20,431 trip/annum. Bioeconomy equilibrium achieved at effort level of 40,862 trips. For biological and economical sustainability reasons, the skipjack resource utilization should be done at MEY level using the effort of 20,431 trip/annum.

Utilization at MEY and MSY level has narrow range, with small profit difference which attract the fishermen to expand the effort. In fact, this expansion may disturb biological and economical equilibrium. As a consequence, the skipjack resource in the Banda Sea may exhaust and may effect the skipjack business activities. Thus, the government need to apply certain policies in relation to good governance of the sustainability of skipjack resource in the Banda Sea.

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