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# The best bio economic estimation of the optimal Katsuwonus pelamis fisheries on the North Coast of Aceh

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**Abstract.** High fishing gear productivity can increase exploitation so that it can endanger the sustainability of resources. This study aimed to examine and find the best estimated model for the status of utilization. Next analysis are assess the level of degradation and depreciation of Skipjack tuna in the North Coast of Aceh (NCA). It conducted using vary methods on analyzing this problem. The methods are using both interview and bio economic Gordon Schaefer model. On bio economic analysis were using Fox Algorithm, Clark Yoshimoto Pooley, Walter Hilborn, and Schnute estimated model. Its result then compared to find best estimated model for the status of utilization Skipjack resources at NCA. The result shows Fox Algorithm has the best estimation model based on suitability on the field and statistical parameter. The highest production on MSY management regime is 3,348 tons per year and MEY management regimes shows maximum value at Rp.40.304 billion per year. Actual Effort are overfished both biologically and economically compared with optimal effort and sustainability effort. Actual Effort reach 8,618 trips per year while the optimal effort for sustainability is 8,039 trips per year and the economic optimum effort is 6.166 trips per year. The average magnitude of the rate coefficient values on degradation is 0.24 and depreciation Skipjack fish resources is 0.44. It means pelagic fish resources at NCA has not been at the level of degraded and depreciated.

## 1. Introduction

Economics can be defined as the study of how society allocates scarce resources. Resource economics might then be defined as the study of how society allocates scarce natural resources [2]. An open-access regime that causes over-exploitation of fisheries resources remains a severe threat [1]. Evidence shows that for centuries the main structural and functional changes in coastal marine ecosystems that have occurred throughout the world are due to overfishing [7].

The decline in fishery resources has driven many studies to determine the effect. Beginning in the 1960s, ecologists, mathematicians, and economists started developing a class of models, which today are referred to as bioeconomic models [10]. In their study used Fox Algorithm estimation model to find that skipjack fishery of banda sea will not cause collapse to the stock.

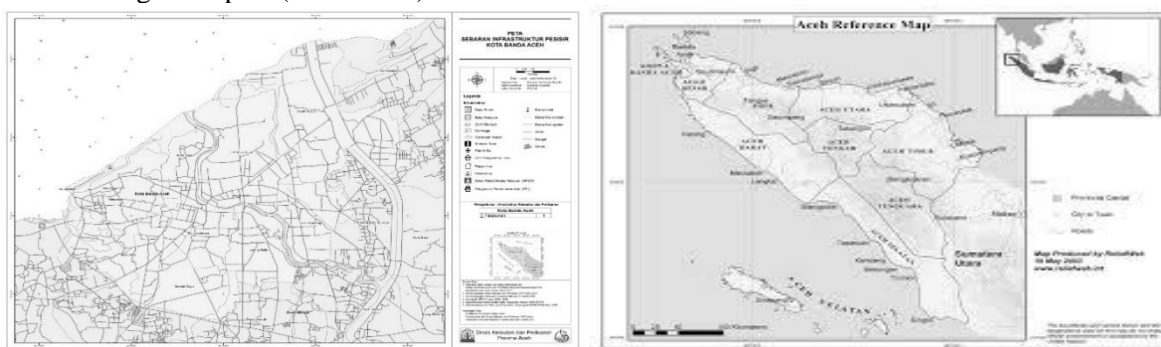


The partial bioeconomic analyses in this paper strongly indicate that biological and economic factors should be considered simultaneously in management analyses [5].

The goal of this study tripled. First, we assess the status of skipjack fisheries on (NCA) because there is no database suitable for management policy regarding the study of stock conditions and the economic value of the skipjack fisheries needed. Second, since this study is the first study to find the best bioeconomic estimation models (Fox, CYP, WH, and Schnute), other bioeconomic studies only use one estimation model, while the assessment of fisheries resources must be appropriate so that the fisheries management policy on (NCA) will be taken is not wrong. Third, after assessing the status of the stock, it is necessary to conduct degradation and depreciation assessments in order to ascertain exactly how much the quality of the resources has been reduced so that it can be found.

## 2. Material and Methods

This study was conducted at Lampulo Ocean Fishing Port, Banda Aceh, Indonesia (Figure 1). The consideration in the election of Lampulo Ocean Fishing Port is because Lampulo Ocean Fishing Port is the largest fishing port in the NCA. This research carried out for five months from February 2013 to January 2014 with three main stages, first preparation, preparation of proposals and questionnaires (two months), second data collection stage (three months); and third the stage of data analysis, preparation and finishing the report (six months).



**Figure 1.** Lampulo ocean fishing port, Banda Aceh, Indonesia.

## 3. Result and Discussion

Calculation of the fishing power index (FPI) is needed if there are more than one fishing gear that exploits fish resources or a particular type of fish. FPI is the level of ability of a fishing gear in catching fish or a particular type of fish in a particular fishing time and area. One of the most dominant fishing gear in fishing activities is used as a reference in homogenizing the number of fishing effort. The standardization of fishing effort is to uniformize the value of effort from several different types of fishing equipment to the type of fishing gear that becomes the standard. The value of the standard effort is obtained from the results of the effort multiplication with the FPI value of each fishing gear studied.

Skipjack tuna which were anchored in Lampulo Ocean Fishing Port were mostly caught using purse seine fishing and stretching fishing. The standardization of fishing gear in Skipjack fish resources in the NCA in this study was conducted on purse seine fishing gear, because it is a fishing gear that has the highest productivity. Therefore, the FPI value for purse seine fishing equipment is equal to one.

### 3.1. Biological Parameter Estimation.

The comparison of the catch coefficient ( $q$ ), the intrinsic growth rate ( $r$ ), and the environmental carrying capacity ( $K$ ) of each estimation model can be seen in Figure 5. Based on the results of the model statistical test, the Fox Algorithm model is the best model because it has an F test significance value below 0.05 and the adjusted  $R^2$  value is higher than other estimation models, besides that the Fox Algorithm model also better reflects the conditions in the field, as seen from the value  $MSY$  is the closest to its actual value. Based on the calculation of the Fox model described in Table 2, the biological parameters obtained from the Fox Algorithm model include: 1) the catch coefficient ( $q$ ), which indicates

that each increase per capture unit will affect 0, 00012 tons per trip; 2) intrinsic growth rate ( $r$ ), where the resources of skipjack fish will grow naturally without any interference from natural symptoms or from human efforts as well as catching 1.87 tons per year; and 3) environmental carrying capacity ( $K$ ), which shows the ability of the ecosystem to support Skipjack fish resource production of 7,164 tons per year.

**Table 1.** Catch per unit effort standardization fishing gear of skipjack tuna in NCA.

Years	Purse Seine					Hand line					Effort	CPUE
	Production	Effort	CPUE	FPI	Effort Std	Production	Effort	CPUE	FPI	Effort Std	Total Std	
2005	758	4210	0.1801	1	4210	6.68	5160	0.0013	0.0072	37.0906	4247	0.1801
2006	1361	4320	0.3151	1	4320	2.34	6621	0.0004	0.0011	7.4269	4327	0.3151
2007	730	12960	0.0563	1	12960	19.89	18752	0.0011	0.0188	353.3383	13313	0.0563
2008	1606	12960	0.1239	1	12960	6.24	20065	0.0003	0.0025	50.3621	13010	0.1239
2009	3100	14544	0.2131	1	14544	2.12	25578	0.0001	0.0004	9.9472	14554	0.2131
2010	2356	14544	0.162	1	14544	2.575	29832	0.0001	0.0005	15.8954	14560	0.162
2011	2636	2606	1.0116	1	2606	4.4	1022	0.0043	0.0043	4.3496	2610	1.0116
2012	2390	2322	1.0294	1	2322	3.5	3377	0.001	0.001	3.4001	2325	1.0294

Source: Secondary data combine from Lampulo Ocean Fishing Port and Marine and Fishing Affairs Board of Banda Aceh City (2005-2012); E = effort.

\*STD=Standard

Skipjack fisheries resources in the NCA have conditions that have been overfishing both economically and biologically when viewed from the difference in effort. The fishing effort in the fishery has exceeded the optimal effort. The actual average efficiency of Skipjack fisheries is 8,618 trips per year, while the optimal effort is 8,039 trips per year. The Maximum Sustainable Yield (MSY) regime is a simple way to manage resources by considering that the over-exploitation of resources causes loss of productivity [8]. The MSY level (Table 3) shows that the Skipjack fisheries resources produced the highest production of 3,348 tons per year, then at the MEY level, while the lowest production of the open access management regime with economic rent was zero. The value of the tuna fish resource rent in the condition of open access is zero, meaning that if the fish resources in the NCA are left open to everyone, then the business competition in this condition becomes uncontrollable resulting in a zero-profit value estimation.

Economists have long argued that biomass that maximizes economic benefits (MEY biomass) from fisheries as a management target [6]. MEY is a concept of long-run equilibrium that refers to the level of output and the level of effort that is appropriate that maximizes economic benefits from fisheries activities [3]. The MEY management regime shows that the economic rent of fisheries resources reaches Rp. 40,304 billion per year with only an effort of 6,166 trips per year. Therefore, the MEY regime is the most economically efficient management regime. This is in accordance with the opinion of Norman-López and Pascoe [9], catching at the point of MEY provides maximum economic benefits both to ship-owners and to wage workers (crew), depending on the profit-sharing system used.

**Table 2.** Comparison of actual data, biological parameters, MSY, MEY and statistical tests on Skipjack resources on North Coast of Aceh.

Pemanfaatan	Actual	Biological Parameters			MSY	Actual % of MSY	MEY	Actual % of MEY	Statistic Test			
		r	q	K					F	Sig F	R2	Adj R2
<b>Fox</b>		1,87	0,00012	7164					7,16	0,04	0,54	0,47
Biomass (x)(ton)					3.582		4.417					
Production (h)(ton)	1.873				3.348	55,95	3.166	59,16				
Effort (E)(trip)	8.618				8.039	107,20	6.166	139,78				
$\pi$ (Million Rp)	4.100				36.583	11,21	40.304	10,17				
% Overfishing	(79)											
<b>CYP</b>		1,89	0,00023	3579629					0,87	0,49	0,30	-0,05
Biomass (x)(ton)					1.789.815		1.790.228					
Production (h)(ton)	1.873				1.687.311	0,11	1.687.311	0,11				
Effort (E)(trip)	8.618				4.016	214,61	4.015	214,66				
$\pi$ (Million Rp)	4.100				34.516.589	0,01	34.516.591	0,01				
% Overfishing	(89.983)											
<b>W-H</b>		0,92	0,00019	17986					0,65	0,57	0,25	-0,13
Biomass (x)(ton)					8.993		9.500					
Production (h)(ton)	1.873				4.120	45,46	4.107	45,60				
Effort (E)(trip)	8.618				2.397	359,60	2.261	381,11				
$\pi$ (Million Rp)	4.100				74.807	5,48	75.076	5,46				
% Overfishing	(120)											
<b>Schnute</b>		0,88	0,00007	9480					0,17	0,85	0,08	-0,38
Biomass (x)(ton)					4.740		6.120					
Production (h)(ton)	1.873				2.083	89,92	1.906	98,26				
Effort (E)(trip)	8.618				6.251	137,87	4.431	194,52				
$\pi$ (Million Rp)	4.100				17.799	23,04	21.415	19,15				
% Overfishing	(11)											

**Table 3.** Utilization of MSY, MEY, and OAE on Skipjack fish resources on the North Coast of Aceh.

Items	Utilization			
	Actual	MSY	MEY	OAY
Production (h) (ton)	1.873	3.348	3.166	2.393
Effort (E) (trip)	8.618	8.039	6.166	12.331
$\pi$ (Million Rp)	4.100	36.583	40.304	0

### 3.2. Economic Parameter Estimation

The data used for input costs and output prices are obtained from data cross section of respondents who use purse seine fishing gear for tuna fish catches. The average amount of the real cost of Skipjack fish resources in Table 4 shows the average real cost of Rp. 3.97 million per ton. The highest input cost for Skipjack fish resources in the NCA was 4.86 million per ton in 2011 and the lowest input cost was Rp. 3.12 million per ton in 2006. While the average price of the largest real output is Rp. 25.35 million per ton in 2013 and the lowest price average output rill of Rp. 14.60 million per ton in 2005. Figure 2 shows the comparison of production, effort, and CPUE in Skipjack fish resources from 2005 to 2012. Figure 8 shows a graph of the amount of production that fluctuates with an increasing trend, only on in 2007, 2010 and 2011 production decreased slightly. The decline in 2007 was 749 tons per year, in 2010 and 2011 to 2,358 tons per year and 2,640 tons per year. This is allegedly caused by significant changes in effort.

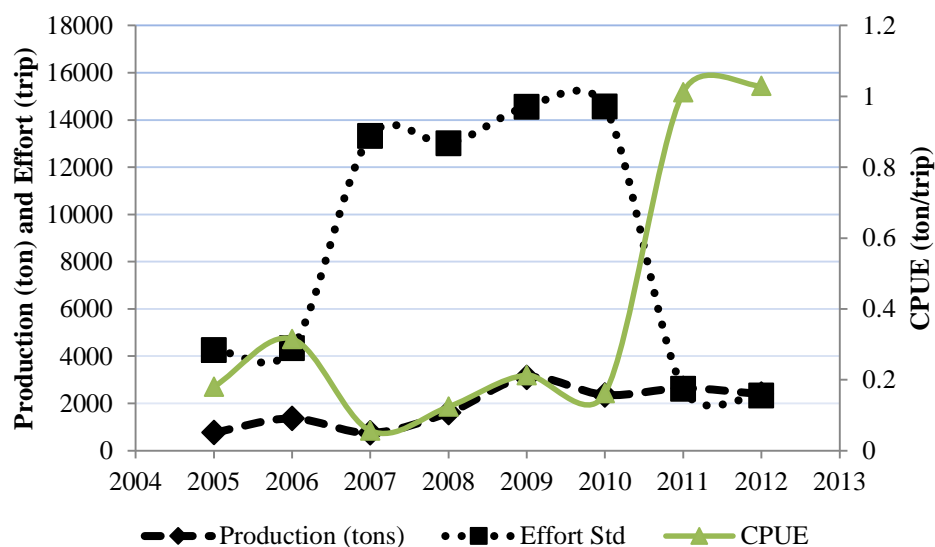
**Table 4.** Data series of real input costs and reel prices of Skipjack fish resources output.

Years	CPI 2002*	Cost of Real Input (Rp Million/Tons)	Price of Real Output (Rp Million/Tons)
2005	259,82	2,83	14,60
2006	286,08	3,12	16,07
2007	337,77	3,68	18,98
2008	384,12	4,19	21,58
2009	377,86	4,12	21,23
2010	429,84	4,69	24,15
2011	445,29	4,86	25,02
2012	393,64	4,29	22,11
2013	451,24	-	25,35
Mean	373,96	3,97	20,47

Source: Results of Data Analysis, 2013

\*Consumer Price Index for fresh fish on the basis of constant prices in 2002

Direct assistance to fishermen affected by the tsunami in 2007 increased the effort from 4,327 trips per year in 2006 to 13,313 trips per year in 2007 thereby increasing the production of skipjack fish. However, the added fleet does not meet the standard criteria of the Indian Ocean vessel, a vessel that is usually used by fishermen in the NCA. The aid ship did not meet the standard criteria of the ship because it was alleged that the ship could not withstand strong currents in the Indian Ocean, so many of the aid ships were damaged. As a result, in 2011 the effort decreased to 2610 trips per year, causing a decrease in production in the same year.

**Figure 2.** Comparison of production, effort, and CPUE of Skipjack fish resources in 2005-2012.

### 3.3. Analysis of degradation and depreciation

Assessment of natural resource depreciation is important because we can know for certain the damage/deterioration in the quality of natural resources, as a result of the exploitation of these resources.

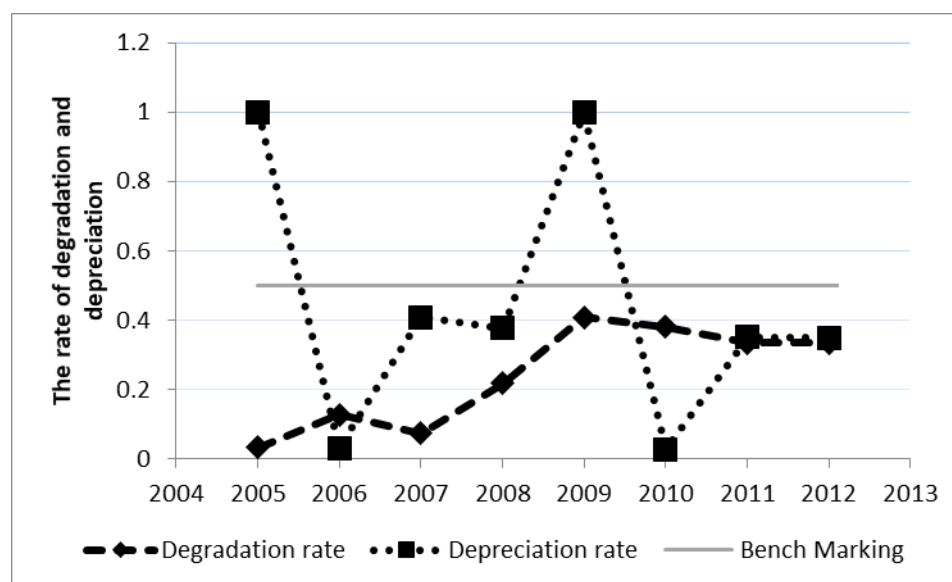
By knowing the value of depreciation of natural resources, the natural resource management policy will be more directed and in accordance with the rules of sustainable development [4]. Therefore, it is necessary to calculate the degradation value and depreciation value of fisheries in the NCA. The

economic value of a quantity called depletion, and the economic value of damage to natural capital quality called degradation [11].

**Table 5.** The results of the analysis of the degradation rate and depreciation rate of Skipjack fish resources in the NCA.

Years	Production		Economic Rent (Rp Million)		Degradation	Depreciation
	Actual	Sustainable	Actual	Sustainable	Rate	rate
2005	764.9	2602.89	-867.1	25960.88	0.03	1
2006	1363.44	2634.12	8414.16	28836.03	0.13	0.03
2007	749.43	1907.04	-34810.84	-12844.57	0.07	0.41
2008	1612.02	2067.83	-19704.62	-9868.6	0.22	0.38
2009	3101.8	1149.48	5881.48	-35561.68	0.41	1
2010	2358.65	1145.47	-11282.87	-40578.84	0.38	0.03
2011	2640.6	1821.1	53382.29	32882.08	0.33	0.35
2012	2393.73	1656.63	42954.29	26654.11	0.33	0.35

In Skipjack fish resources, the depreciation rate coefficient in 2005 and 2009 has exceeded the tolerance value, even reaching its maximum point (Table 5). It can be interpreted that the decline in the quality and quantity of Skipjack resources in 2005 and 2009 has decreased to a maximum level when viewed in monetary units, which has experienced considerable losses. The rate of degradation of Skipjack fish resources in the range of 2005 to 2012 has not exceeded the value of tolerance so it can be interpreted that the decline in the quality and quantity of Skipjack resources in the span of 2005 and 2010 is still in a reasonable stage when viewed in the physical unit of fish resources (Figure 3). Although it has tended to decline from year to year, it has not yet reached its maximum level.



**Figure 3.** The rate of degradation and depreciation of Skipjack fish resources in the NCA in 2005-2012.

There are differences in graph patterns between the rate of degradation and the depreciation rate, but overall the graph pattern of degradation rate and depreciation rate in Skipjack fish resources is almost the same, so that it can be said that the condition of Skipjack fish resource biology is very influential on the economic rent that fishermen will get in the North Coast Waters.

#### 4. Conclusions

Fox Algorithm has the best estimation model based on suitability on the field and statistical parameter. The highest production on MSY management regime is 3,348 tons per year and MEY management regimes shows maximum value at Rp.40.304 billion per year. Actual Effort are overfished both biologically and economically compared with optimal effort and sustainability effort. Actual Effort reach 8,618 trips per year while the optimal effort for sustainability is 8,039 trips per year and the economic optimum effort is 6.166 trips per year. The average magnitude of the rate coefficient values on degradation is 0.24 and depreciation Skipjack fish resources is 0.44. It means pelagic fish resources at NCA has not been at the level of degraded and depreciated.

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