Estimation of MSY and MEY of skipjack tuna (*Katsuwonus pelamis*) fisheries of Banda Sea, Moluccas

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Abstract. Potency of skipjack tuna fisheries, *Katsuwonus pelamis,* at Banda Sea has long been exploited and currently leads to overfishing condition. The objectives of this study are to analyze the potency and utilization of skipjack tuna at Banda Sea as well as the economic value of this fishery based on biological data. Methodology used in this study consists of interview and Gordon-Schaefer as well as Fox Algorithm. Result from Schaefer shows that maximum sustainable yield (MSY) of skipjack tuna at Banda Sea was *h* (180,487 ton, effort E = 302 fishing vessel, π = 10,270,567,583,276); maximum economy yield (MEY) with the *h* value was (180,487, E = 302 fishing vessel, π = 10,270,567,585,004, total cost TC = 2,066,559, total revenue TR = 10,287,776,328,454, break event point (BEP) with the value of E = 440 fishing vessel, TC = IDR 3 billion pole and line vessel^{-1} yr^{-1}; TR = IDR 8 billion pole and line vessel^{-1} yr^{-1}) whilst Fox Algorithm shows skipjack tuna MSY at Banda Sea was *h* (161 ton, E = 119 fishing vessel, π = 2,398,914,580); MEY was *h* (161 ton, E = 113 fishing vessel, π = 2,698,358,661, TC = 811,493,467, TR =9,156,420,437, BEP with the value of E = 140 fishing vessel, TC = IDR 7.5 million pole and line vessel^{-1} year^{-1}; TR = IDR 8 billion pole and line vessel^{-1} yr^{-1}.
Key Words: MSY, MEY, skipjack tuna, Banda Sea, fishing, vessel.

Introduction. Skipjack tuna (*Katsuwonus pelamis*) migration en route for Banda Sea started from center of the Pacific Ocean (Arrizabalaga et al 2015; Yen & Lu 2016; Wang et al 2016; Matsumoto et al 2016), passing through northwest Pacific Ocean (Mugo et al 2010; Kolody & Hoyle 2015; Arrizabalaga et al 2015; Rooker et al 2016), east Pacific Ocean (Fink & Bayliff 1970), Atlantic Ocean (Fonteneau 2015; Muhling et al 2015; Arrizabalaga et al 2015), through Amami-Oshima Kagoshima waters, Japan (Ashida & Horie 2015), continues through Indian Ocean, Reunion Island (Nikolic et al 2016; Arrizabalaga et al 2015; Grande et al 2016), entering Indonesian waters through Bone Bay (Jamal et al 2011; Jamal et al 2014; Zainuddin et al 2015; Uktolseja 1987), passing through Stern Flores waters (Mallawa et al 2014), then through Mamaju waters (Safruddin et al 2014; Zainuddin et al 2015), Banda Sea (Widodo et al 2015; Hidayat et al 2014).

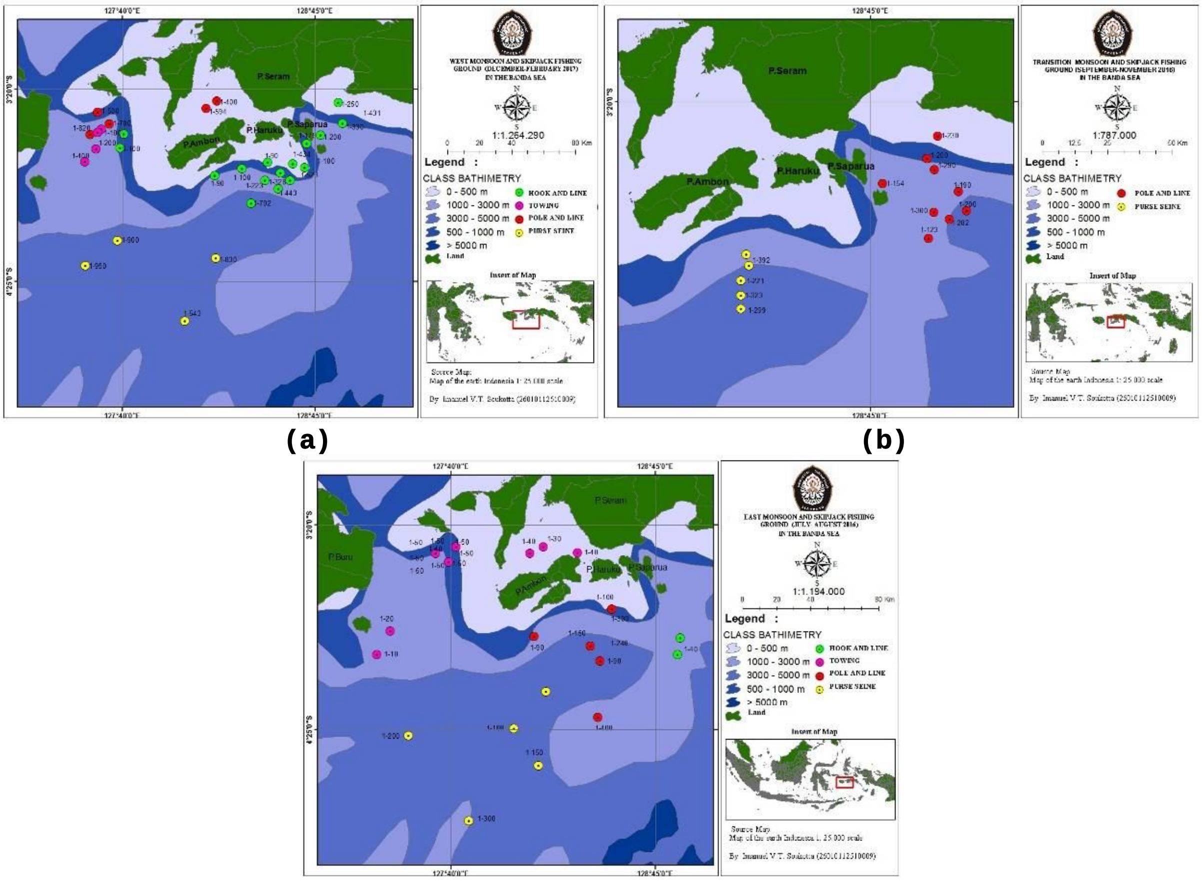
During the period between 2006-2015, the highest production of skipjack tuna fishery was achieved at 2010 with the value of 150,000 ton then it declined to 54,853 ton in 2015 (Statistic Bureau Ministry of Maritime Affairs and Fisheries of Ambon City 2006-2015). From year to year, exploitation level of this fishery in Banda Sea already passes the Maximum Sustainable Yield (MSY). Waileruny et al (2014) in their study show that exploitation level of skipjack tuna in Banda Sea currently had passed the MSY level. Hidayat et al (2014) show that exploitation level of this skipjack tuna in Banda Sea has reached 67% MSY, whilst Widodo et al (2015) in their study show that 26% of the skipjack tuna caught in Banda Sea was under allowable size catch.

One of the weaknesses in deciding sustainable fisheries management policy in Ambon City is the accurate data availability related to potency and level of exploitation of small pelagic fishery. Ministry of Marine and Fisheries Affairs of the Republic of Indonesia decree No. 107/Kepmen-KKP/2015 about tuna, skipjack and mackerel tuna management plan, skipjack potency in term of MSY has not been established yet (Tuhuteru et al 2015; Widodo et al 2015). Sustainability of big pelagic fish management required in Kota Ambon covers quota arrangement, invest development in fish trolling vessels (compared to pole and line), human resource empowerment, integrated business management and empowering of *sasi,* the indigenous knowledge in fisheries management.

Up to this present time there is no suitable data base as a basis for policy management for skipjack tuna fishery at Fisheries' Management Area WPP 714 of Banda Sea, hence a study on stock condition, economic value of the fisheries is required. The objectives of this study therefore are to examine the condition of skipjack tuna stock and the economic value of this fishery based on bioeconomic aspect.

Material and Method

Description of the study sites*.* The study was conducted between August to December 2016 at Banda Sea waters (Figure 1). Primary data source was taken from skipjack vessel log book covering: fishing area position, number of catch, whilst secondary time series data was obtained from Nusantara Fishing Port of Ambon covering year 2006 to 2015 (10 years data).



(a) (b)

(c)

Figure 1. Study site at 714 fishing area: (a) west monsoon (December- February); (b) trasition monsoon (September-November); (c) east monsoon (June-August). Source: Logbook May 2016-February 2017.

Production surplus analysis*.* Production surplus analysis through catch per unit effort (CPUE) was analyzed according to Gulland (1969). Skipjack tuna can be fished with several fishing gears, therefore standardization should be made for all fishing gear and the calculation of fishing power index (FPI) was conducted according to Gulland (1969).

The Fox model (1970) has several distinct characteristics from the Schaefer model, namely the growth of biomass following the Gompertz growth model. The surplus production model was first developed by Schaefer (1954), whose form was initially the same as the logistic growth model.

Results and Discussion

Catch per unit effort Schaefer Model and Fox Model. There are four fishing gears used in skipjack tuna fishery *i.e.* pole and line, purse seine, towing and hook and line. All these gears have different productivity and therefore should be standardized through fishing power index approach, a method to predict standard fishing effort (Taylor & Prochaska 1985). From all four fishing gears, pool and line being the most productive gears, hence fishing power index for each fishing gear was then calculated using pole and line as a standard fishing gear. Garstang (1900) and Smith (1994) introduced the idea to measure fishing effort of each fishing vessel per day by calculating efficiency of several fishing gears to become one kind of fishing gear based on total year catch data. Fishing vessel capacity can be defined as a year catch production and fishing effort efficiency (Gulland 1956). Beverton & Holt (1957) explained ratio between fish catch per unit time effort of the vessel with others as a standard which is 1 which was more operational, pointed to standard vessel, the effort expected to be constant (Table 1).

Table 1

CPUE standardization fishing gear of skipjack tuna in Banda Sea

Fishing Power Index				*Total*	*Actual production*	*CPUE*
Pole & line	*Purse seine*	*Towing*	*Hook & line*	*effort*	*(ton)*	*(ton/E)*
11	0.08	1.32	0.118	63	45,023	715,0
16	0.10	0.32	0.030	38	39,899	1061,8
17	0.12	0.04	0.032	31	32,880	1051,1
23	0.13	0.09	0.251	92	70,383	761,3
34	0.06	0.02	0.169	78	150,713	1922,1
43	0.07	0.06	0.021	66	110,948	1673,9
63	0.45	0.75	0.069	199	52,693	264,9
73	1.56	0.29	0.204	274	54,945	200,8
98	1.87	2.58	0.136	557	49,842	89,5
99	0.51	1.44	0.602	690	54,853	79,4

Source: Secondary data from Marine and Fishery Affairs Board of Ambon City (2006-2015); E = effort.

Estimation of Catch Per Unit Effort (CPUE), Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY) with Schaefer model. Regression analysis between fishing effort and skipjack fish production produce the relationship with the equation of y = -1.9801x + 1,195.6 with the correlation coefficient r = 0.71 and determination coefficient R^2 = 0.5023. Graphically this relationship can be seen in Figure 2. This equation implies that when there is no effort (b = 0) then skipjack stock available will be 1,195 ton vessel^{-1}. The regression coefficient, b = -1.980 explains that when standard effort decrease will cause an increase in CPUE. The determination of the coefficient R^2 = 50.23% means that variation in CPUE 50.23% is explained by the effort, and there are 49.77% factors which have an effect on CPUE of skipjack fishery as well, but they have not been analyzed in this study. The correlation coefficient was 0.71 means that this correlation between CPUE and standard effort was quite strong (Figure 2). From the analysis it was found that growth rate r = 0.99263, fishing gear coefficient q = 1.64393x102 ton trip^{-1}, and carrying capacity K = 727,310 ton yr^{-1}.

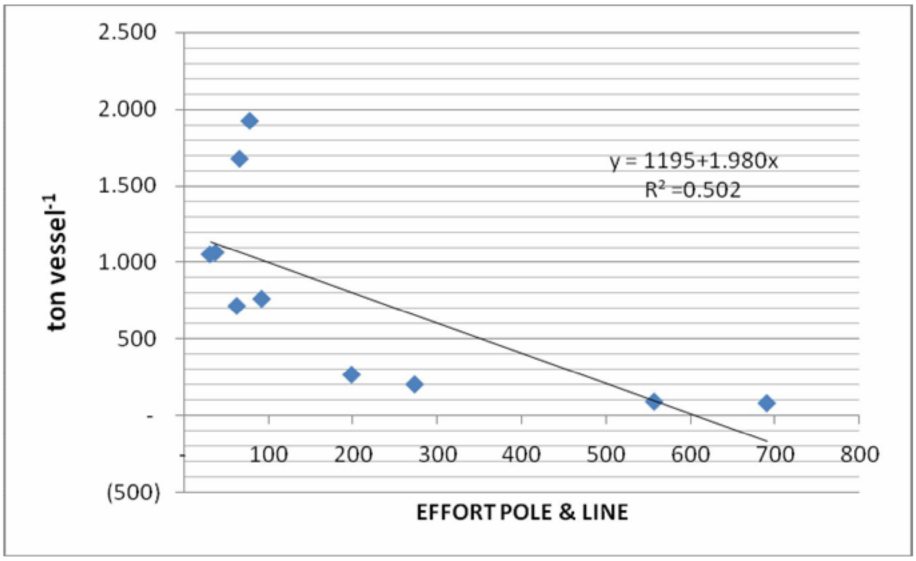


Figure 2. CPUE Schaefer of skipjack tuna.

Estimation of MSY and optimum effort (E_{opt}) of skipjack at Fishery Management Area (FMA) 714 of Banda Sea using linear Schaefer model shows that skipjack MSY was 180,487 ton and E_{opt} was 302 fishing vessel (Figure 3), whilst Waileruny et al (2014) found MSY for skipjack at Banda Sea was 30,954 ton with E_{opt} was 21,251 trip with MEY = 20,431 ton and E_{opt} equal to 32,905 trip. This means that the trips used in the Waileruny et al (2014) study are trips in this analysis relating to the timing of the vessel's visit to a particular place, not the unit of day or week of operation. Thus when the ship comes to the fishing grounds and catches one place, then moves to another place then the counted trip is the time to come and go in that place instead of the old day of operation as the sense of the actual trip.

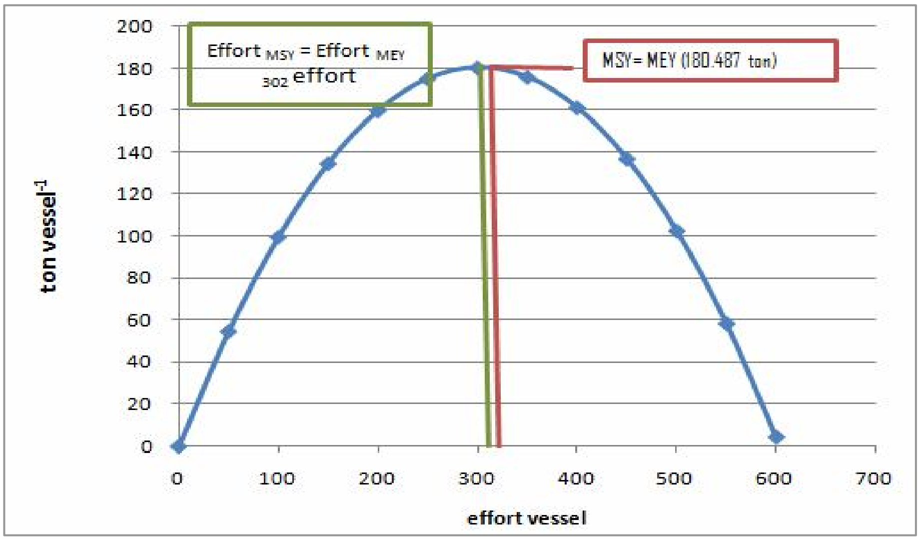


Figure 3. Schaefer stock equilibrium curve (MSY) of skipjack tuna at Fishing Area Management 714 of Banda Sea.

Actual effort of skipjack tuna caught at FMA 714 by 690 fishing vessels on 2015 was 54,853 ton fish. According to the regulation of the Ministry of Agriculture of the Republic of Indonesia Nr. 473a/1985, total allowable catch (TAC) is 0.8 MSY, with this regulation the TAC is equal to 144,390 ton, hence total skipjack caught at 2015 was far below (37% TAC) the TAC permitted. If 144,390 ton divided by 317 ton (total ton/total effort), one unit of pole and line skipjack vessel can catch 455 ton skipjack per year. The remaining

63% measured by 89.537 ton/465 (ton 1 unit vessel per year) will give 192 unit vessel per year.
Skipjack production at MEY of Schaefer model is expected to give a revenue (π) of IDR. 10,270,567,583,276 yr^{-1}. Increase in fishing effort will disturb resource sustainability as shown on Table 2 and Figure 4. The studies of Norman-López & Pascoe (2011) and Pascoe et al (2016) explained that input-output was obtained when fish catch reach maximum revenue. This study shows that break even point was occurred at an intercept between total cost (TC = IDR 3 billion yr^{-1}) and total revenue (TR = IDR 8 billion $vessel^{-1}$ yr^{-1}), where skipjack tuna pole and line has relatively high revenue, operated at 440 vessel unit and this is lower than actual vessel unit on 2015 (690 vessel).

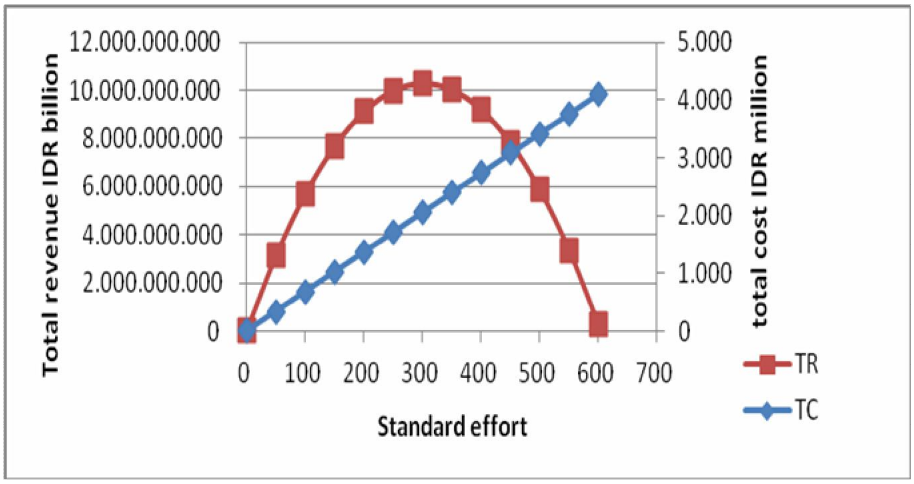


Figure 4. Maximum economy yield (MEY) curve of Schaefer model from skipjack fishery at FMA 714 of Banda Sea.

Estimation of CPUE, MSY, and MEY according to Fox Model. Regression analysis between standard effort and CPUE according to Fox Model produced the exponential equation of $y = 2.71e^{-0.0114x}$ indicating that when there is no effort (b = 0.0114) then CPUE per vessel would be 2.71 ton. From this analysis it was found that determination coefficient R^2 = 0.89% (Figure 5). Other results came from this analysis *i.e.* intrinsic growth coefficient r = 1.39832x10^2 ton yr^{-1}, fishing gear coefficient q = 5.89747x10^4 ton $trip^{-1}$, and carrying capacity K = 459.519 ton yr^{-1}.

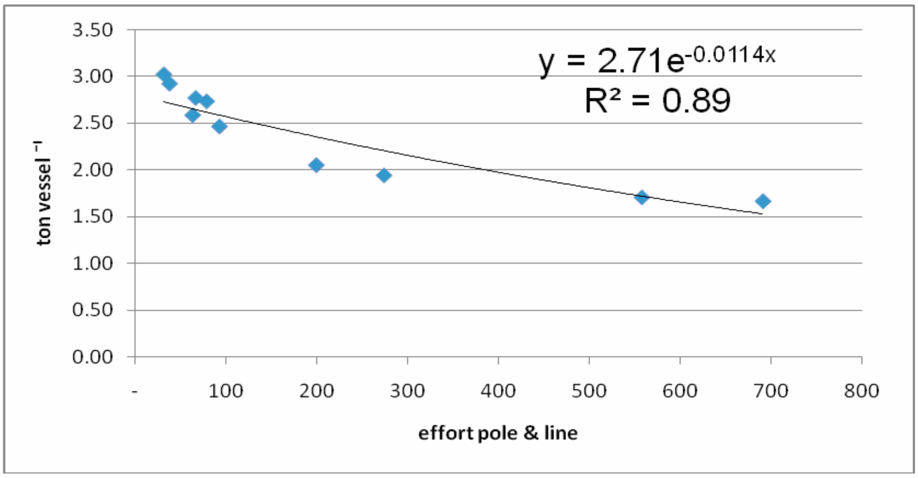


Figure 5. Relationship between effort and CPUE of skipjack tuna according to Fox model.

Fox model algorithm analysis shows that MSY of skipjack tuna at FMA 714 of Banda Sea was 161 ton with E_{opt} = 119 vessels (Figure 6 and Table 3), whereas Waileruny et al (2014) found MSY of skipjack at Banda Sea equal to 30,954 ton with E_{opt} = 21.251 trip and MEY = 20,431 ton with E_{opt} = 32.905 trip.

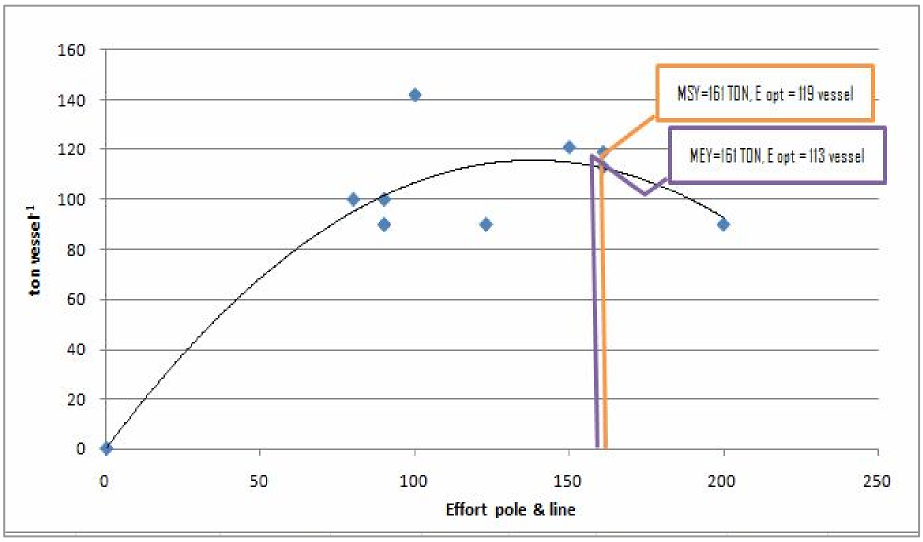


Figure 6. Balance stock curve (MSY) of skipjack tuna at FMA 714, Banda Sea, according to Fox Algorithm model.

According to Indonesia Marine and Fisheries Affairs regulation of the Republic of Indonesia Nr. 473a/1985: total allowable catch (TAC) was set at 0.8 of the MSY, hence the TAC for skipjack tuna at FMA 714 is 129 ton and this is far below the MSY. Additionally C_{actual} (54,853/129) is 42.7%. If TAC (129 ton) is divided by 317 (total ton/total effort) then one unit of skipjack tuna pole and line vessel can catch 0.41 ton yr^{-1}. The remaining 58% measured by 54.724 ton/129 (ton 1 unit vessel yr^{-1}) will give 134.9 fishing vessel yr^{-1}. With the current skipjack tuna stock condition at Banda Sea and result from TAC analysis, the skipjack tuna fishery in Banda Sea thus still under fished.

Norman-López & Pascoe (2011), and Pascoe et al (2016) explained that input-output is reach when fish catch reach maximum revenue. This study shows that break even point of skipjack tuna pole and line fishery was reached at cross section of TC (IDR 811 million $vessel^{-1}$ yr^{-1}) and TR (IDR 9 billion $vessel^{-1}$ yr^{-1}) (Figure 7). This skipjack tuna pole and line fishery has relative high revenue, 140 fishing vessel already gave suitable catch at MSY and MEY 161 ton yr^{-1}.

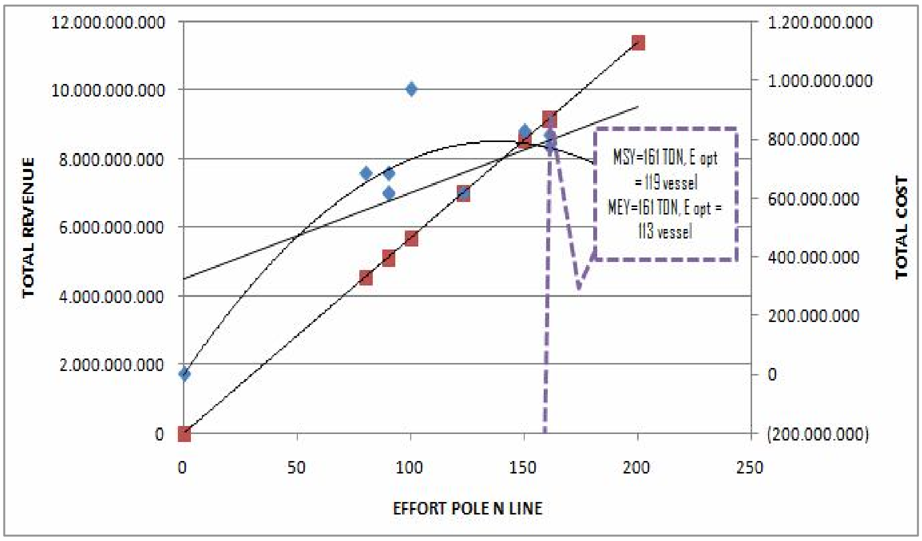


Figure 7. Maximum economy curve (MEY) of skipjack tuna fishery at MFA 714 of Banda Sea according to Fox Model.

Table 2

Revenue calculation based on MST, MEY of Schaefer model

MSY = r.K/4	E_{MSY} = *r/(2.q)*	*MEY = rK/4 – (c/2p)^2(r/q^{2}K)*	E_{MEY} = *r/2q – (c/2p)(r/q^{2}K)*	*π (MSY) = ph-pE*	*π(MEY) = ph-pE*	*TR = p.h*	*TC = c.E*	*Price of fish*	*Cost of fishing*
Ton	E	Ton	E	IDR	IDR	IDR	IDR	IDR million ton^{-1}	Vessel yr^{-1}
180.487	302	180.487	302	10.270.567.583.276	10.270.567.585.004	10.287.776.328.454	3.066.559.000	57	6.845.000

Table 3

Revenue calculation according to the value of MSY, MEY of Fox model

MSY = r.K/4	E_{MSY} = *r/(2.q)*	*MEY = rK/4 – (c/2p)^2(r/q^{2}K)*	E_{MEY} = *r/2q – (c/2p)(r/q^{2}K)*	*π (MSY) = ph-pE*	*π(MEY) = ph-pE*	*TR = p.h*	*TC = c.E*	*Price of fish*	*Cost of fishing*
Ton	E	Ton	E	IDR	IDR	IDR	IDR	IDR million ton^{-1}	Vessel yr^{-1}
161	119	161	113	2.398.914.580	2.698.358.661	9.156.420.437	811.493.467	57	6.845.000

Conclusions. Schaefer Model gave E_{opt} 302 fishing vessel, MSY 180,487 ton which > than 144,390 ton TAC, thus there should be an increase in catch approximately close to TAC of skipjack tuna population stock at Banda Sea. Algorithm Fox model gave E_{opt} 119 fishing vessel, MSY 161 ton > TAC. Fox algorithm: E_{opt} 119 vessels, MSY 161 ton > 129 ton TAC. Fox model for skipjack fisheries at Banda Sea shows that the skipjack fishery will not cause the stock to collapse. The skipjack tuna in Banda Sea is under fished.

Schaefer model identified maximum revenue of MSY and MEY at over fished condition was IDR. 16,285,928,858 with E_{opt} = 302 vessel yr^{-1}, MEY = 691 vessel yr^{-1}, maximum benefit at BEP = 440 vessel yr^{-1}, whilst maximum MSY and MEY according to Fox model was IDR. 9,156,420,437 with E_{opt} = 113 vessel yr^{-1}, maximum benefit BEP was 140 vessel yr^{-1}.

We suggest the following:

- Schaefer model for 1 unit pole and line yr^{-1} can catch 465 ton yr^{-1} skipjack tuna with 149 vessel yr^{-1} at Banda Sea;

- Fox model for 1 unit pole and line can catch 0,41 ton skipjack tuna yr^{-1} with allowable number of ship was 134,9 vessel yr^{-1}.

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Received: 28 February 2017. Accepted: 19 April 2017. Published online: 30 April 2017.
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How to cite this article:
Soukotta I. V. T., Bambang A. N., Sya'rani L., Saputra S. W., 2017 Estimation of MSY and MEY of skipjack tuna (*Katsuwonus pelamis*) fisheries of Banda Sea, Moluccas. AACL Bioflux 10(2):435-444.