POSSIBLE USE OF A STOCK–PRODUCTION MODEL INCORPORATING COVARIATES (ASPIC) FOR STOCK ASSESSMENT OF RAYS IN THE INDIAN OCEAN OF INDONESIA

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ABSTRACT

Limited-data sheets, in general, arestill major challenges in managing shark and ray. An analytical model, such as age-structured models has been developed recently to estimate population status of fisheries. However, this model must require sufficient data especially for tropical fisheries, as it is difficult to measure age of many fishes and often impractical in these fisheries. Catch-effort data arearguing to be the affordable and best available in tropical-based fisheries including Indonesia's fisheries. This research aims to examine the potential application of A Stock-Production Model Incorporating Covariates (ASPIC) to investigate stock statusof ray in the Indian Ocean(FMA 571, 572 and 573) based on catch-effort data in 2005-2015. The results showed that the stock status became to be pessimistic because of substantial increase in catches in recent years. The results from most of scenarios indicate the current status of rays in Indian Ocean may be overfishing and overfished (B_{2016}/Bmsy=0.304; F_{2015}/Fmsy=1.45). An effort reduction urgently required to ensure the long-term benefits of ray population about 45% of an effort in 2015 (24,506 unit that equal to gillnet).ASPIC is potentially used to examine the status of ray, however, improvement on data collection must be crucially needed to provide appropriate stock analysis.

Keywords: ***ASPIC; ray; Indian Ocean; Indonesia***

INTRODUCTION

Information on shark and ray population is limited globally (Dulvy *et al.*, 2014) that added complexity layer of managing and conserving the population (Lack *et al.*, 2009). This condition is one of major challenges for Indonesia(Dharmadi *et al.*, 2015), by consideringa significant contribution on shark and ray product globally (FAO-FishStatJ, 2015).Population of ray is commonly unsighted in managing elasmobranch in Indonesia despite the significant value of catch being landed. Ray in Indian Ocean of Indonesia (consist of Fisheries Management Area/FMA 571, 572 and 573) contributed about 35% of total ray landed in Indonesian waters (DGCF, 2016).

Recently, maximum sustainable yield (MSY) is used as a limit boundary to minimize stock collapsing(Quinn *et al.*, 2005). Catch per Unit Effort (CPUE) commonly used as a proxy of abundance of population being exploited, but comprehensive knowledge required to interpret the status of population by considering fish biology and fisher behaviour (Simeon *et al.*, 2018). However, the traditional calculation assumed equilibrium condition to estimate the MSY level. A Stock Production Model Incorporating Covariates (ASPIC) is used to examine a non-equilibrium state of the surplus production model, such as Schafer, Fox and Pella-Tomlinson. ASPIC allows the user to estimate parameters by direct optimization, by grid search for model shape and by fixing model shape (Prager, 1994) and has been used to examine the status of tuna (Prager, 1992).

This research aims to examine the potential application of A Stock-Production Model Incorporating Covariates (ASPIC) to investigate stock status of ray in the Indian Ocean (FMA 571, 572 and 573) based on catch-effort data in 2005-2015.

MATERIALS AND METHODS

Data collection

The analysis used catch data published by DGCF (2016),unpublished standardized fishing effort estimated by the Research Institute for Marine Fisheries (RIMF) from period of 2005 – 2015. It aggregate catch of ray in Indian Ocean of Indonesia (Figure 1) that refer to three Fisheries Management Area (FMA) i.e. FMA 571 (Malaka Strait), 572 (Western part of Sumatra waters) and 573 (Southern part of Java, Bali and West Nusa Tenggara waters). The fishing effort was standardized into the number of the vessels operating bottom set gillnet.

As appeared in the annual capture fisheries statistic published by the Directorate General of Capture Fisheries for year 2005 – 2015 (DGCF, 2016), the catch of ray fishery in FMA 573 consists of a number of species, namely stingray (including whipray), devil ray, manta ray, eagle ray, shovelnose ray, guitarfishand other rays. It assumes the species composition appeared in the capture fisheries statistic published by DGCF is reflected the actual condition.

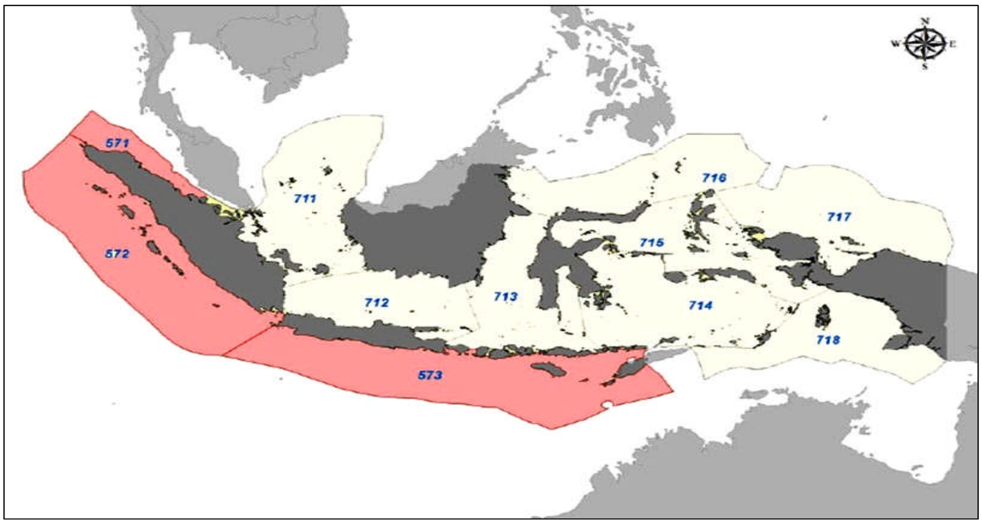

Figure 1. Management unit of FMA 571, 572 and 573 – red areas (National Commission for Stock Assessment, 2010).

Data analysis

The analysis for this paper uses non-equilibrium biomass dynamics model (Haddon, 2011). A general formulation of the fish biomass dynamics model, as described or used by Polacheck *et al.* (1993)are:

$$B_{t=1} = B_t + g(B_t) - C_t \qquad \text{.........(1)}$$

Where:

B_t = the exploitable biomass at the beginning of year *t*;
B_{t+1} = the exploitable biomass at the beginning of year *t*+1;
$g(B_t)$ = surplus production as a function of biomass at year *t*;
C_t = the catch during year *t*.

The surplus production model $[g(\square_t)]$ used in this paper was selected between logistic model of Schaefer (1957) and Fox (1970)as follows:

The Schaefer model:

$$g(B_t) = r.B_t(1 - B_t / K) \qquad \text{.........(2)}$$

The Fox model:

$$g(B_t) = r.B_t.[1 - \ln(B_t)/\ln(K)] \qquad \text{.........(3)}$$

Where:
r = the intrinsic growth rate parameter;
K = the average biomass level prior to exploitation.

Catch per unit effort at year *t* (U_t) is used as an index of relative abundance for year t (Fox, 1970; Schaefer, 1957), and the relationship between U_t and B_t is:

$$U_t = q.B_t \qquad \text{.........(4)}$$

Where: q = the catchability coefficient.

Estimation of the production parameters used least square method with 20,000 trials of Monte Carlo simulation and 1,500 trials of bootstrapping. The analysis was undertaken by using ASPIC program developed byPrager (1994), with the input as appeared in Annex 1.

RESULTS AND DISCUSSION

Results

Development of Fishing Effort, Catch, and Catch per Unit Effort

The fishing effort of ray fishing fleet in the three FMAs tends to be stable during 2005 – 2007, and decreases until 2011, then increases in 2013 (Figure 1). The minimum and the maximum fishing effort during 2005 – 2015 are 14,297 and 26,072 units, respectively.

The quantity landed tends to plateau during 2005 – 2015 with insignificant fluctuation(Figure 2 dotted line). The catches landed in 2014 and 2015 are about 15.7 thousand and 13.1 thousand tons, respectively. Meanwhile, the effort reached the peak in 2013 by 43.8 thousand units before decrease in the following years (Figure 2 dashed line). The catch per unit effort (CPUE) tends to fluctuate during 2005 – 2015, but generally increase. The CPUE in 2014 and 2015 are about 0.52 and 0.53, respectively (Figure 2 solid line). Meanwhile, the minimum and the maximum CPUE during 2005 –

2015 are 0.31 and 0.64 tons, respectively.Based on the statistical data of capture fisheries, published by DGCF (2016), the ray in the three FMAs contributed about 20-32% of the total production of ray in Indonesia during 2005 – 2015. About 70% of the total ray production consisted of stingray that includedwhipray.

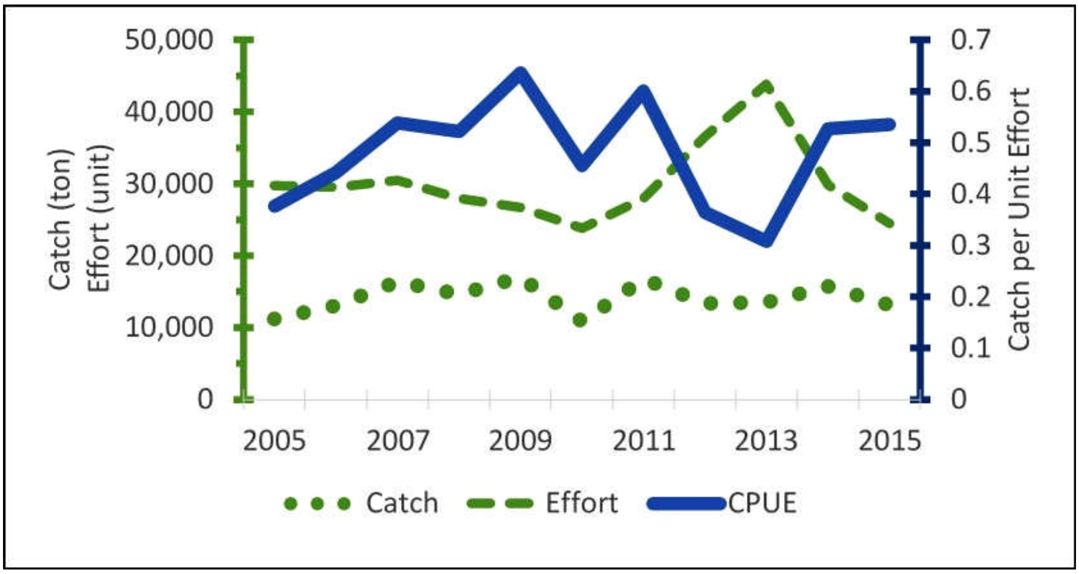

Figure 2. Fishing effort, total catch, and catch per unit effort, of ray in Indian Ocean, 2005 – 2015(DGCF, 2016).

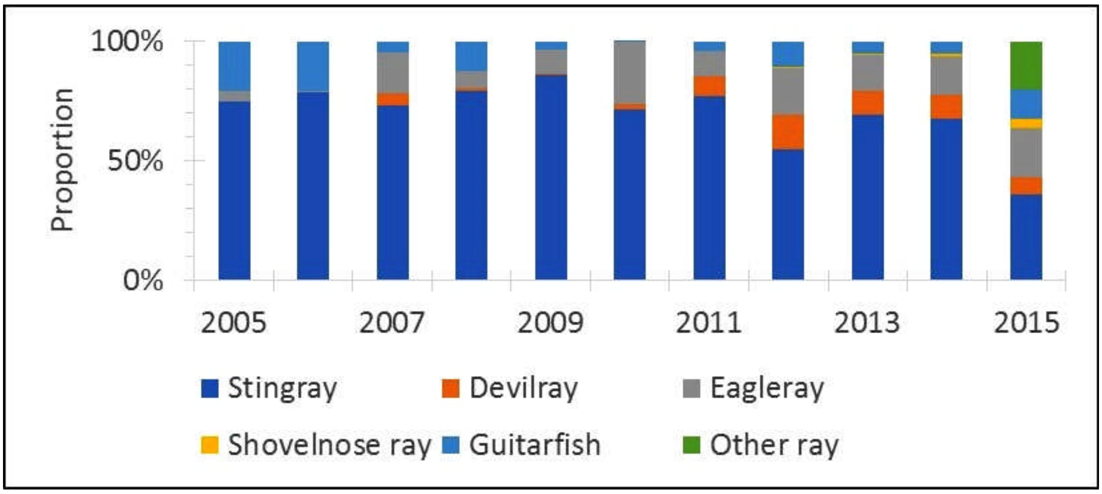

Figure 2. The proportion of ray landed in FMA 571, 572 and 573, 2005 – 2015.

Fishery Production Model and Optimal Production

The values of parameters resulting from analyses of the production of ray by using the Schaefer and the Fox models were presented inTable 1. Based on the result of analysis, the Schaefer model was used by considering the goodness of fit to the data of this model (0.650).

Table 1. The estimated values of parameters and determination coefficients of the production model of ray in the Indian Ocean of Indonesia

Parameter	Unit	Schaefer Model
r	-	1.1
q	10^{-5}	3.083
K	10^{5} tons	1.164
R^2	-	0.074

Note: r = 2*FMSY for Schaefer model (Prager, 1994)

Table 2. The optimum value of ray biomass and production, and the optimum level of fishing mortality and fishing efforts of ray in the Indian Ocean of Indonesia

Parameter	Symbol	Unit	Point estimate
Maximum sustainable yield	MSY	tons	31,960
Fishing mortality at MSY	F_{MSY}		0.55
Catchability coefficient	q	10^{-5}	3.083
Estimated yield in 2016	Y_{2016}	tons	17,690
Biomass at MSY	B_{MSY}	tons	58,190
Relative biomass at MSY	B_{2016}/B_{MSY}		0.30
Relative fishing mortality at MSY	F_{2015}/F_{MSY}		1.45

The estimated optimum value of ray biomass and production, and the estimated optimum level of fishing mortality and fishing efforts of the ray in the three FMAs are presented inTable 2. The results of the analysis indicate that the ray stock in three FMAs could produce sustainable production at a maximum level of 31.96 thousand tons/year resulting from fishing mortalityby0.55.

In 2015, the fishing mortality (F_{2015}) was estimated to be about 0.80, which was higher than the estimated fishing mortality when MSY reached (F_{MSY}) by 0.55. Therefore, the relative fishing mortality (F_{2015}/F_{MSY}) was about 1.45. On the other hand, the estimated fish biomass in 2015 (B_{2015}) was lower than the fish abundance at MSY (B_{MSY}). The B_{2015} was 15,260 tons, while the B_{MSY} was about 58,190tons. The relative fishing mortality and the relative biomass in 2015, i.e. F_{2015}/F_{MSY} = 1.45 and B_{2015}/B_{MSY} = 0.26. The fish biomass was projected to be 17,690 tons in 2016, and the relative fish biomass (B_{2016}/B_{MSY}) was about 0.30.

Development of Fish Stock Abundance and Fishery

The development of catches per unit of fishing effort (CPUE) resulting from observation and estimation is presented inFigure 3. The estimated CPUE tends to be decrease around 1.75 tons during 2005 – 2008, then increase siginificantlyto the highest level, i.e. 4.5 tons, in 2015. The estimated CPUE in year 2015 was about 4.5 tons, while the estimated CPUE when the MSY reached was about 4.0 tons.

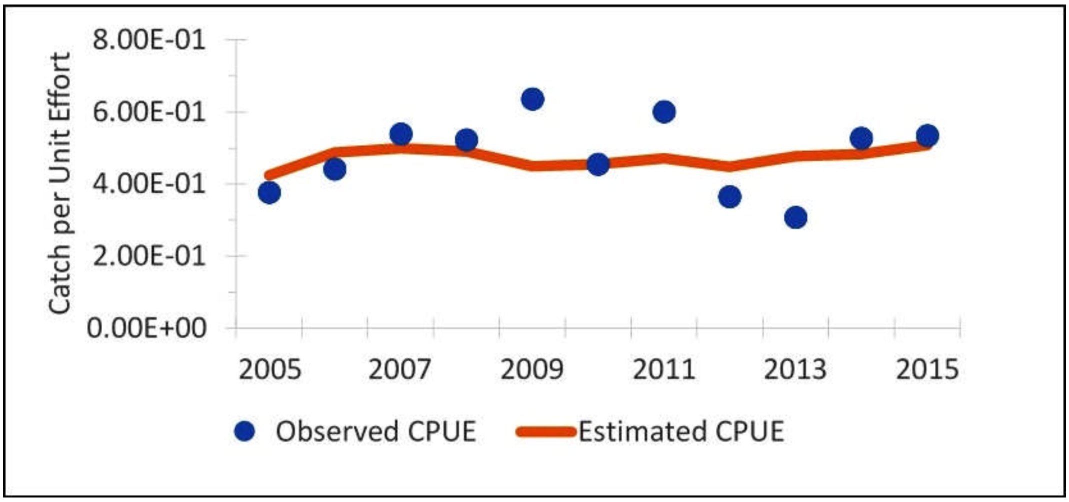

Figure 3. Observed and estimated catch per unit effort of ray in the three FMAs.

The development of fishing pressures and affected ray biomass in three FMAs was shown from the plot of relative fishing mortality and relative fish biomass presented in Figure 4a. In 2005, the fisherieswas overfishing and the ray stock was overexploited, as shown from F_{2015}/F_{MSY} >1 and B_{2015}/B_{MSY} <1. The fishing pressure increased since 2015 to 2015. As the fishing pressure increased dramatically, the abundance of stock decreased rapidly. In 2015, the fishing pressure was at overfishing level, i.e. F_t/F_{MSY}>1. In 2015, the fish stock was in overexploited condition, i.e. B_t/B_{MSY}<1, and needed longer time to recover. It was estimated that the ray stock would be continually depleted and $B_t/B_{MSY}>1$ in 2016 (Figure 4b).

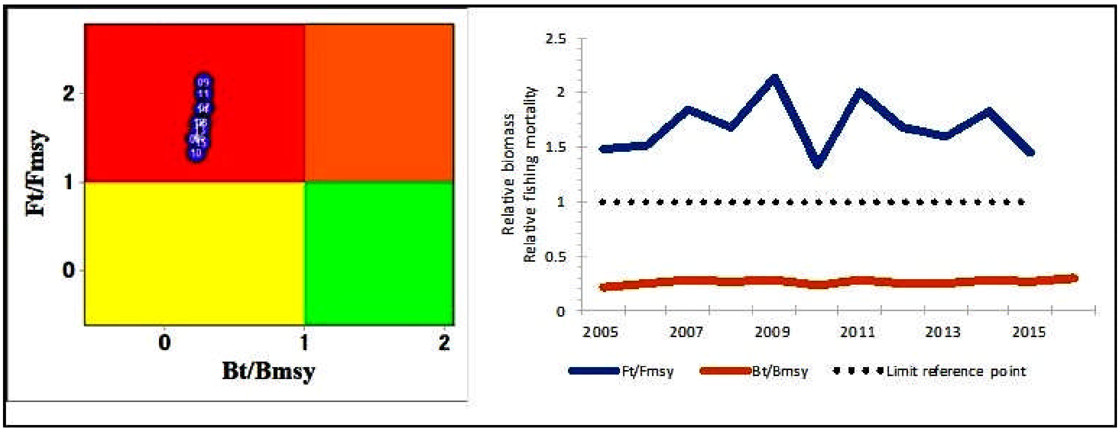

Figure 4.(A) Kobe plot, and (B) trajectory of the ray stock and fishing intensity in three FMAs, 2005 – 2015.

Discussion

It argued trophic shifting between shark and ray, where the landing of ray tends to increase and overtake the shark (Dulvy *et al*., 2014). It calls global attention to conserve it by setup four priorities, i.e. saving shark and ray species, managing shark and ray fisheries for sustainability, ensuring responsible trade in shark and ray products, and encouraging responsible consumption of shark and ray products (Brautigam *et al*., 2015).

Result of the analysis showed that the ray in three FMAs (571, 572 and 573) is on the RED quadrant of the Kobe Plot its mean the status of ray in those FMAs is over exploited and overfishing, interestingly this condition happened since 2004 until present time, one of the explanation about this stable overfishing and over exploited condition was happened for more than 14 years is the interaction between the species.

Monk (2012)simulated the multispecies demersal fishery and state that the fished multispecies demersal fishery tends to have stable biomass and could be fished at a higher fishing mortality rates rather than estimated using the single species. Further analysis for species composition shifting in the multispecies demersal fishery needs to done, in order to investigate the impact of fishing mortality to the biomass.

Rebuilding scenarios need to be proposed to increase the overfished biomass, five scenarios to control the effort could be proposed to reduce fishing mortality and rebuild the biomass. First scenarios to control the effort is number of fishing boat moratorium by stop issuing new licence to enter the fishery, second scenario is to reduce the effort by stopping the renewal of expired fishing licences, third scenario to be consider is reducing fishing days from the fishing boat, implementation this scenario could utilized the local traditional knowledge, i.e stop fishing during Friday pray and also stop fishing during the religion celebration such as Idulfitri, Ramadhanor Islamicnew year. Fourth scenario to reduce fishing effort is gear modification using less destructive fishing gear. Last scenario to establish sanctuary area for ray(Martins *et al*., 2018). Moreover, it is urgent to review the data collection of ray and to improve it. Since, it is arguing that the catch and effort that was fishy. It demonstrates the potential use of ASPIC in estimating the status of ray.

CONCLUSION

This study and analysis reveal the status of ray in Indian Ocean of Indonesia. Ray stock is over exploited and the fishery is at overfishing level. Biomass level is at very low level (less than 0.3 from the B_{MSY}) and need biomass rebuilding strategy. Four scenarios are proposed mainly to reduce the fishing effort and to establish fisheries sanctuary. However, improvement on data collection crucially required to provide appropriate stock analysis.

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