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POSSIBLE USE OF LENGTH-BASED SPAWNING POTENTIAL RATIO FOR SKIPJACK (*Katsuwonus pelamis*) IN INDONESIA'S ARCHIPELAGIC WATERS

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ABSTRACT

A harvest strategy development for skipjack tuna (Katsuwonus pelamis - SKJ) fishery within Indonesia's archipelagic waters (Indonesian Fisheries Management Areas - FMAs 713-715) has been initiated, which is mandated within its National Tuna, Skipjack and Neritic Tuna Management Plan. Information on the stock status or indicator is needed, since it is one essential component of a harvest strategy. In fact, the lack of catch and effort data from Indonesian fishery, in general, is still an international concern. A method to assess the stock status for data poor fisheries namely Length-based Spawning Potential Ratio (LB-SPR) was developed. This study attempted to investigate a possible use of the LB-SPR to estimate spawning potential ratios of SKJ using length data from Indonesian pole and line fishery collected by the port-based sampling program (a collaborative project between Indonesia and the Western and Central Pacific Fisheries Commission (WCPFC). There is a decreasing trend in the estimated SPR from 2010 to 2015 unless 2014, indicating that impact of fishing on the resources increased over the study period. If the SPR20% is adopted as limit SPR, then the estimated values of SPR less than SPR20% suggested that recruitment overfishing might be occurring. In fact, the results should be considered as preliminary results, as the size data of SKJ from pole and line might not be capturing large SKJ or the nature of SKJ in Archipealgic waters has smaller size in general compare to other region that potentially hampered the asymptotic selectivity assumption within the LB-SPR model underestimating the SPR. Further work is required to gather complete representative of length data of SKJ covering all length classes of the fishery.

Keywords: Spawning potential ratio; skipjack; Indonesia's archipelagic waters

INTRODUCTION

Management measure for several tuna species, that are highly migratory species and widely distributed across the ocean, has been conducted by several regional fisheries management organizations (RFMOs). Skipjack tuna (*Katsuwonus pelamis* - SKJ) is one of significant species in global tuna fisheries as the catches highest of the all tuna species. In the Western and Central Pacific – Convention Area (WCP-CA), SKJ was 68% of the total tuna catches from 2013-2015 (Williams & Terawasi, 2014; Williams & Terawasi, 2015; Williams & Terawasi, 2016) and slightly decreased in 2015 to 67% of the total tuna catch (Williams & Terawasi, 2017). The stock assessment for this species in the Pacific area has been done by the Pacific Community – the Western and Central Pacific Fisheries Commission (WCPFC). The Western and Central Pacific Ocean (WCPO) has been known to be the biggest SKJ fishery (Senina *et al*., 2016b), which mainly targeted by purse seine and pole and line (Senina *et al*., 2016a). The results of the current stock assessment (2014) suggested that SKJ in the WCPFC convention area is still in healthy condition, i.e. overfishing is not occurring and the stock is not overfished (McKechnie *et al*., 2016). However, spawning biomass of SKJ is on decreasing trend despite high levels of recruitment (Rice *et al*., 2014). Depletion rate of SKJ noted previously is low and is approaching the limit reference point of $0.2SB_{F=0}$ (Rice *et al*., 2014). In the WCPFC statistical area, the PL catch mostly comprised of SKJ, ranged between 69% and 98% from 1960 to 2014 (OFP & SPC., 2015).

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SKJ are found in almost whole Indonesian waters, except in the whole Java Sea, partly of both Malacca Strait and South China Sea. SKJ are also dominant species of Indonesian tuna catch (Satria *et al*., 2014; Satria *et al*., 2015; Satria *et al*., 2016; Satria *et al*., 2017). National catch of skipjack from (FMAs) 713-717 were 262.927 tons which 68% of the SKJ catches were belonging to Archipelagic waters (713-715). In the Indonesian Fisheries Management Areas (FMAs) 713-715 (Annex 1), SKJ is main target for pole and line, purse seine and troll line, but are also being caught by small scale oceanic gillnets. These three FMAs are archipelagic waters, and part of the region 4 of the WCPFC SKJ stock assessment region. Among key landing places for tuna fisheries operating in these FMAs are Bitung (North Sulawesi), two landing sites in Kendari Bay (South East Sulawesi) – Kendari Fishing Port and Sodohoa, Ambon, Maumere, Larantuka, Bone, Mamuju, Majene, Gorontalo, Ternate, Sorong, Fakfak and Tual (Appendix 1).

A port-based sampling program, a collaboration between Indonesia and the Western and Central Pacific Fisheries Commission (West Pacific East Asia – WPEA project), has been implemented in Bitung, Kendari, and Sodohoa since 2010, later expanded to Sorong in 2012i, Majene since 2014 and in Gorontalo since 2016 for most of fishing gear that operating in the Indonesia's FMAs 713 – 715 but also in the FMAs 716 and 717. The main objective of the project is to estimate annual tuna catch landed by gear and by species and collect length data for tropical tuna including SKJ at selected sites by trained enumerators. Large amount of length data of SKJ were recorded since the program commenced.

Indonesia initiated a harvest strategy development for SKJ fishery within its archipelagic waters (FMAs 713-715), which has been mandated within its National Tuna, Skipjack and Neritic Tuna Management Plan since 2015. Information on the stock status or indicator is needed, since it is one component of a harvest strategy (Dichmont *et al*., 2011). Several conventional stock assessment methods require a time-series catch and effort data, which many fisheries, categorized as data limited fisheries, are unable to provide the required data (Bentley, 2015; Costello *et al*., 2015). In fact, the lack of catch and effort data submission from Indonesian fishery to WCPFC, in general, is an international concern (Williams, 2014). Although Indonesia has implemented a national logbook system, the data quality and coverage are still an issue to be addressed (Williams, 2016). However, a management could not refrain. Fortunately, a new method has been developed for data poor fisheries to assess the stock status, namely the Length-based Spawning Potential Ratio (LB-SPR, http://whatsthecatch.murdoch.edu.au, Hordyk *et al*., 2015a, b). The SPR is commonly used to indicate the stock status, by setting the limit and target reference points for the fisheries (Clark, 2002). The WCPFC uses the unfished biomass ($SB_{F=0}$) as one of reference points, and adopted 20%$SB_{F=0}$ as the limit reference point (Rice *et al*., 2014) and 50% $SB_{F=0}$ as the interim target reference point (WCPFC, 2015) for SKJ. This study attempted to investigate a possible use of the Length-based Spawning Potential Ratio (LB-SPR) method (Hordyk *et al*., 2015a, b) to estimate the spawning potential ratio for SKJ caught by pole and line fishery within the Indonesia's archipelagic waters FMAs 713, 714 and 715 using length data from pole and line vessels.

MATERIALS AND METHODS

A total of 107,093 SKJ from the pole and line vessels were sampled and measured by enumerators at the ports of Bitung (FMA 715), Kendari (FMA 714), Sodohoa (FMA 714) and Sorong (FMA 715) between 2010 and 2015. Number of SKJ sampled by year and sampling location from 2010 – 2015 is given in Table 1. For all samples collected from the four ports, the lengths of skipjack ranged between 14 - 92 cm fork length (cmFL), with median 40 cmFL (Figure 1).

Table 1. Number of SKJ sampled from pole and line vessels by year and sampling location from 2010 – 2015. Source: WPEA port-based sampling program.

Sampling location	Number of SKJ sampled					
	2010	2011	2012	2013	2014	2015
Bitung	16,682	12,381	14,845	14,661	21,509	316
Kendari	10,378	8,913	2,291	947	459	571
Sorong	-	-	-	-	3,116	-

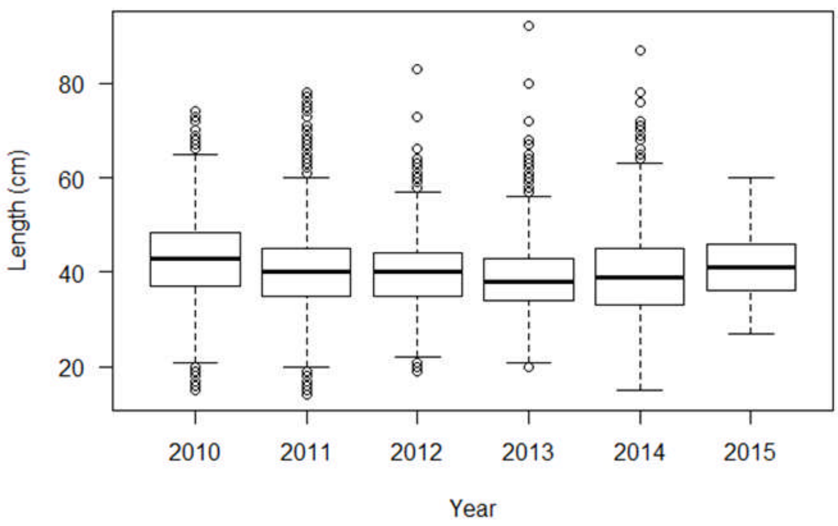

Figure 1. Boxplot for length data by year collected from pole and line vessels by the WPEA port-based sampling program from 2010 to 2015.

Some biological parameters of SKJ are required to calculate the LB-SPR. The parameters are M/K, L_∞, L_{50} and L_{95}, where M is the instantaneous rate of natural mortality; K is the von Bertalannfy growth coefficient; L_∞ is the asymptotic length estimated from the von Bertalannfy growth curve; and L50 and L95, are the lengths at 50% and 95% maturity, respectively. There are two sets of parameters used in the analysis (Table 2), called as Par1 and Par2. The parameter values for Par1 and Par2 are similar, except for L_∞ i.e. 93.6 cmFL for Par1 and 70 cmFL for Par2 (Table 2). The model estimates the selectivity-at-length and the ratio F/M (F is the instantaneous rate of fishing mortality), then these are used to calculate the SPR. The LB-SPR model is equilibrium based and assumes length sample is representative of the population, stock is at or near equilibrium and asymptotic selectivity (large fish that are missing in the catch have all been caught) (Hordyk *et al*., 2015a). The SPR is calculated using the following equations (Hordyk *et al*., 2015b):

$$SPR = \frac{Total\ Egg\ Production\ _{Fished}}{Total\ Egg\ Production\ _{Unfished}} \quad \text{.................................(1)}$$

$$SPR = \frac{\sum(1-\tilde{L}_x)^{(M/k[(F/M)+1])}\tilde{L}_x^b}{\sum(1-\tilde{L}_x)^{M/k}\tilde{L}_x^b} \quad \text{……....................... (2)}$$

for $x_m \le x \le 1$

where, $\tilde{L}_x = 1 - 0.01^{(x(k/M))}$ and $\tilde{L}_x^b = \tilde{W}_x$ or the standardized weight at standardized age *x.* The LB-SPR analysis was done in R software using LBSR package developed by Hordyk *et al*. (2015a). Lengths data from the four sampling locations were combined to calculate the SPR.

Tabel 2. Biological parameters of SKJ for the LB-SPR analysis using two sets of parameters.

	M/K	L_∞	L_{50}	L_{95}	Source
Par1	1.4	93.6	40	41	Hoyle *et al*., (2011), Tanabe *et al*. (2003)
Par2	1.8	70	39.8	41.6	Merta & Gafa (1999)

RESULTS AND DISCUSSION

Results

Across all length data measured, around 48% of the SKJ are less than 40 cmFL i.e., less than the size at maturity (L_m or L_{50}). The proportion of the fish less than its L_{50} by gear generally increased from 2010 to 2015 (Figure 2). The annual length distributions of SKJ sampled from pole and line vessels between 2010 and 2014 indicate a shift in mode to smaller fish (Figure 2), may indicate the decreasing size of the SKJ. Although shifting of the length distribution may be influenced by selectivity of the gear used (Pilling *et al*., 2015). The length distributions of SKJ from pole and line fishery were also presented by landing location, which can be seen in Figure 3 for Bitung and Figure 4 for Kendari. The size distribution of SKJ from Bitung and Kendari between 2010 and 2014 showed a change in mode to smaller fish (Figures 3 and 4). In the meantime, the size distribution of SKJ from Bitung peaked in smaller size (<L_{50}), whereas from Kendari peaked in larger size (>L_{50}).

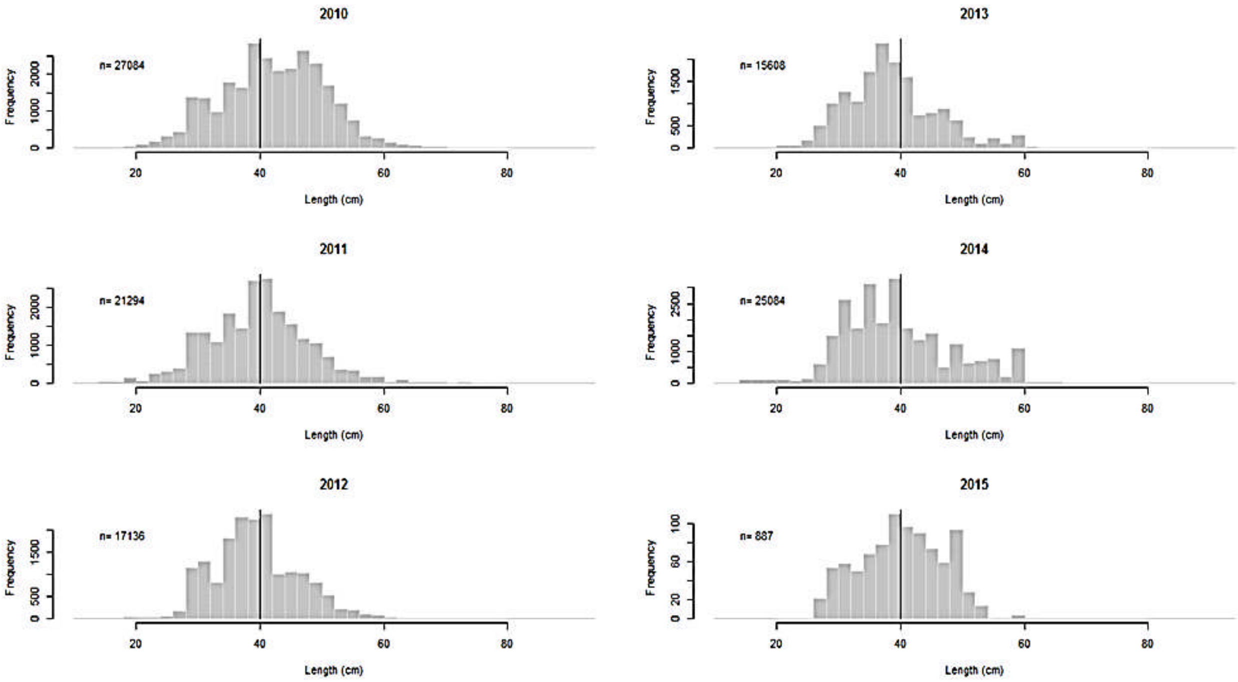

Figure 2. Length frequency of SKJ sampled from pole and line by year. The solid black line is the L_m or L_{50}.

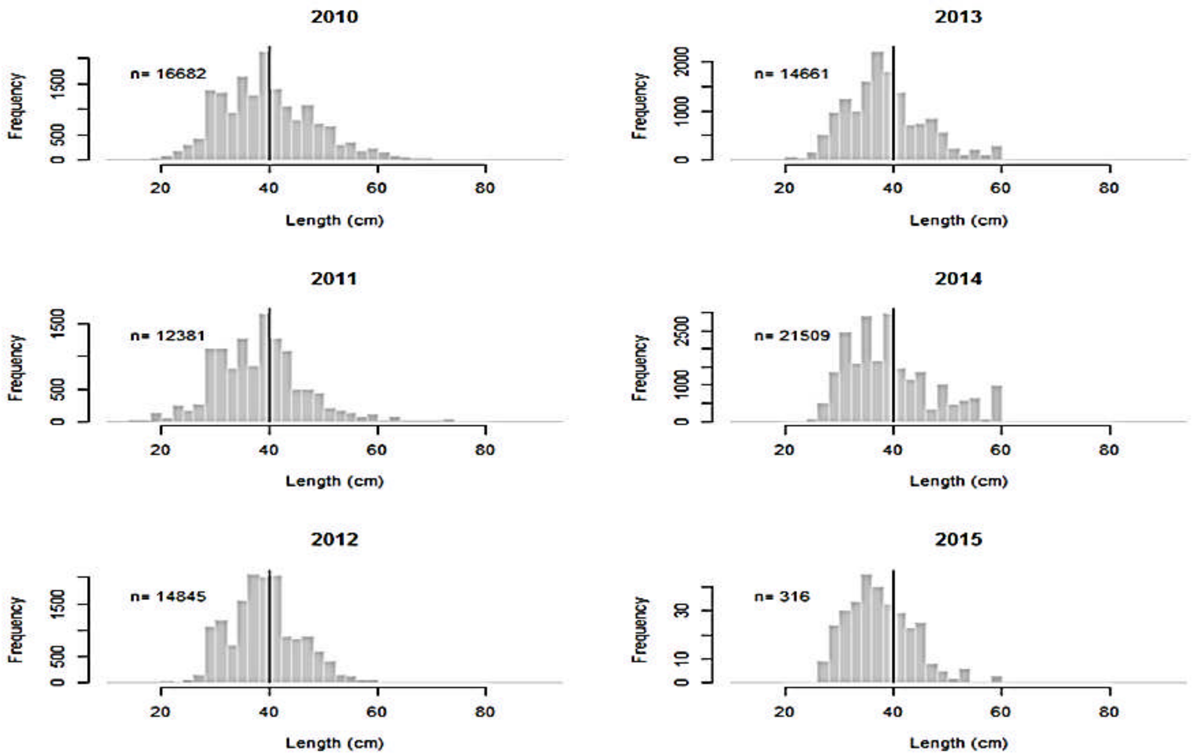

Figure 3. Length frequency of SKJ sampled from pole and line landed in Bitung by year. The solid black line is the L_m or L_{50}.

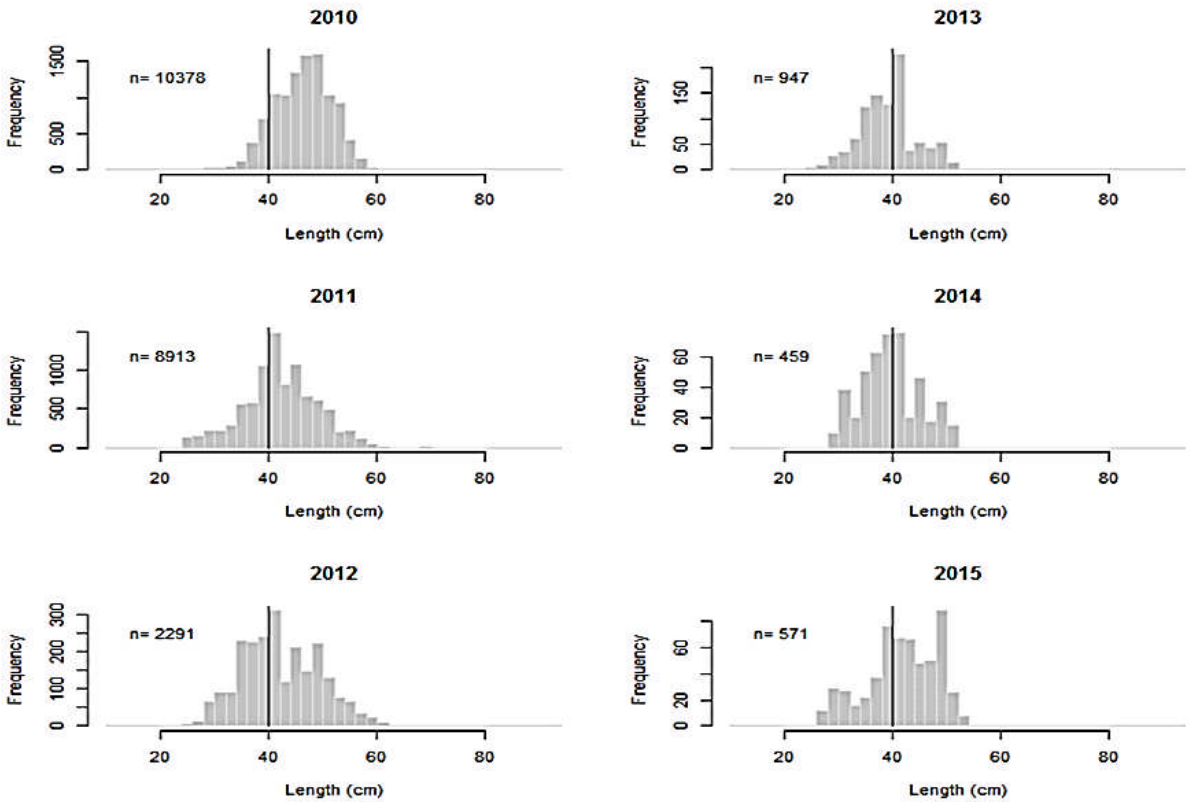

Figure 4. Length frequency of SKJ sampled from pole and line landed in Kendari by year. The solid black line is the L_m or L_{50}.

Tabel 3. Estimated F/M by year and by parameters used (Par1 and Par2)

	2010		2011		2012		2013		2014		2015	
	Est. F/M	SD	Est. F/M	SD	Est. F/M	SD	Est. F/M	SD	Est. F/M	SD	Est. F/M	SD
Par1	6.86	0.17	5.67	0.10	5.93	0.11	5.01	0.08	3.29	0.04	11.47	2.19
Par2	1.54	0.05	1.51	0.04	1.77	0.04	1.46	0.03	0.73	0.02	3.19	0.63

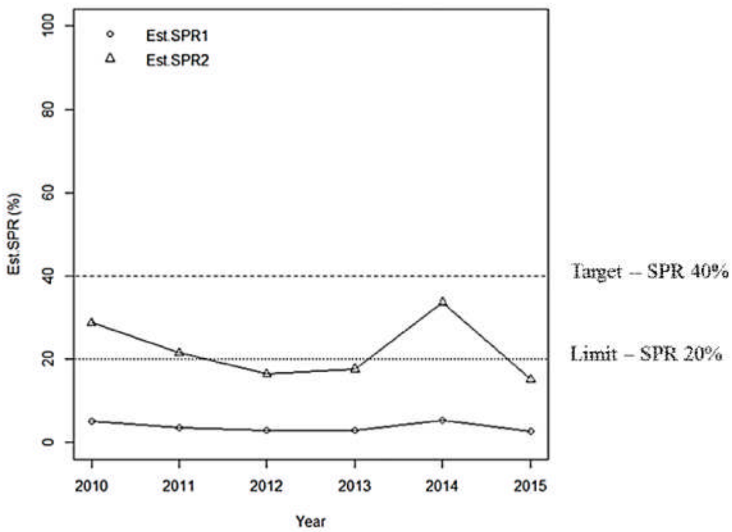

Figure 5. Estimated SPR for SKJ from pole and line fishery operating in the Indonesia's archipelagic waters – FMAs 713-715. The two lines show the target and limit SPR commonly used.

The estimated the F/M for each year using Par1 was higher than that Par2. The estimated values of F/M were between 3 and 11 for Par1, and between 0.7 and 3.2 when using Par2 (Table 3).

There is a decreasing trend in the estimated SPR for SKJ from the pole and line fishery for both Par1 and Par2, except in 2014 (Figure 5). The estimated SPR is lower than 10% across all studied period for Par1, which is less than the common target and limit SPR values. Whereas, the estimated SPR using Par2 were higher than that using Par1, which ranged between 15% and 34% (Figure 5). The estimated SPR in 2010, 2011 and 2014 when using Par2 were higher than SPR 20% (the common Limit SPR used).

Discussion

A large proportion of small SKJ (less than its Lm) was sampled by the port sampling program. This is different with the historical size data of SKJ in the region 4 of the WCPO SKJ stock assessment region (mostly from Japanese pole and line data from 1972 to 2009) that show higher proportion of larger SKJ (> 40 cmFL) was sampled relative to the smaller SKJ (Rice *et al*., 2014). The annual length distribution of SKJ samples collected from Bitung and Kendari indicate a shift in mode to smaller fish between 2010 and 2014, which in turn might suggest the decreasing size of SKJ.

The length frequency data showed that only small number of large SKJ are found during sampling activity (2010-2015) from the Indonesian pole and line fishery and SKJ with size over 83 cmFL. This may suggest that there are only small number of available large SKJ (> 40 cmFL) and no SKJ over 83 cmFL found in the Indonesian archipelagic waters. However, the Japanese longline vessels operated in the WCPO caught SKJ with the size up to 90 cm FL, with the peak size around 60 cmFL within the region 4 (Rice *et al*., 2014). It is still being questioned about the availability of the SKJ larger than 83 cmFL in the Indonesian archipelagic waters (FMAs 713 – 715), this may be the nature of SKJ in Archipelagic waters has smaller size in general compare to other regions.

The LB-SPR model is a relatively new method developed for a limited data (data-poor) fishery that is an extension of Beverton-Holt model that use the literature of life history on the species of interest (Prince *et al*., 2015a, b). Prince *et al*. (2015c) has applied this model to estimate the SPR for 12 species of Indo-Pacific coral reef fish in Palau, which showed that the model is easy to implement for a data-poor fisheries because of less data required. However, the LB-SPR approach was not intended to substitute the comprehensive stock assessment methods, instead of more practicable and minimum expenses while able to give advice to the fishery manager.

The decreasing trend in the estimated SPR for SKJ from the Indonesian pole and line fishery may indicate the increase impact of fishing on the stock's spawning availability (SAW2011-2-WCPFC training material). This is consistent with the stock assessment results of the WCPFC that showed a decreasing trend in the SPR of SKJ in the region 4 (Rice *et al*., 2014). If Indonesia adopts the limit SPR as SPR20%, then the lower estimated SPR (compared to the limit SPR) suggested recruitment overfishing maybe occurring in the fishery. From the two biological parameter sets, the LB-SPR analysis seems to be sensitive to the parameter values of SKJ, i.e. showed a higher values of SPR when using different set of biological parameters (with the lower L_{∞}).

As the model assumes asymptotic selectivity, having a data set with many fish below the Lm and few larger fish indicate to the model that all large fish (>83 cmFL) have been removed, generating a very low SPR value. More data from other gears may be needed to investigate whether larger individuals of samples were occurred and will affects to the model assumption and overall results. This preliminary result should be considered with caution of an exercise and the assumptions behind the LB-SPR method. This highlights the importance of collecting complete representative of length data from the population, i.e. covering all length classes of the fishery.

CONCLUSION

This study is a first attempt to apply the LB-SPR method to the SKJ data from pole and line vessels operating in the Indonesian archipelagic waters. There is a decreasing trend in the estimated SPR from 2010 to 2015 unless year 2014, indicating that impact of fishing on the resources increased over the study period. If the SPR20% is adopted as limit SPR, then the estimated values of SPR less than SPR20% suggested that recruitment overfishing might be occurring. However, the results should be considered as preliminary results, considering the size data of SKJ from the pole and line fishery used in the analysis might not be capturing large SKJ caught by other gears in the Indonesian archipelagic waters. If this is the case, the asymptotic selectivity assumption within the LB-SPR model would underestimate the SPR.

Further work is require to gather complete representative of length data of SKJ, i.e. covering all length classes of the fishery, is important.

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Appendix 1. Map showing the Indonesian fisheries management areas (FMAs) and the main tuna landing places in the FMAs 713-715. Modification of the Ministerial Regulation of Marine Affairs and Fisheries No. 18/ 2014 on Indonesian Fisheries Management Area.