Reproductive Biology of Skipjack Tuna (*Katsuwonus pelamis*) in Indonesian Exclusive Economic Zone

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Abstract

Skipjack tuna (*Katsuwonus pelamis*) is a tropical tuna species and has been a historically exploited in the south and western part of Indonesia waters (south eastern Indian Ocean). The objective of this study was to determine length at first maturity (Lm_{50}) of female skipjack obtained from area south of Bali. Samples were collected from April to September 2018, and April to October 2019. A total of 230 ovaries with length ranged between 33-72 cm FL. Fresh ovaries were immediately fixed using a 10% buffer-formalin solution then histologically prepared using the paraffin method and HE staining (Harris-Haemotoxylin and Eosin). Ovaries containing advanced yolked, migratory nucleus or hydrated oocytes and/or POFs were classed as mature, and ovaries with unyolked or early yolked oocytes as the MAGO but with maturity markers present were classed as mature as well. Ovaries containing unyolked and early yolked oocytes as the MAGO but no POFs, atresia or maturity markers were classed as immature. Size at first maturity (Lm_{50}) of female skipjack in Indian Ocean southern Bali was 42 cm FL (41 - 42.9 cm FL).

Keywords: reproductive biology, histology, skipjack tuna, Indian Ocean

Introduction

Skipjack tuna (*Katsuwonus pelamis*) is a tropical tuna species and has been a historically exploited in the south and western part of Indonesia waters (south eastern Indian Ocean). Skipjack tuna is one of the most exploited species after yellowfin tuna (*Thunnus albacares*) by handline fisheries in southern Bali (Sulistyaningsih et al., 2011).

Accurate information of reproductive characteristics of tuna is an important factor in determining the regeneration capacity of a population. While macroscopic analysis of ovaries is useful for rapid field-based assessment of reproductive stage and maturity, incorrect assignment can have implications for precision and accuracy of the parameter estimates derived from these data. Microscopic/histological analysis is the most appropriate method to accurately

assess maturity status and estimate reproductive parameters for tuna (J. H. Farley et al., 2013; Schaefer, 1998; Zudaire et al., 2010).

Several studies regarding the gonad maturity level and biology reproductive of skipjack tuna using microscopic (histological) and macroscopic (visual morphology) observation methods have been carried out in the Indonesian waters (Hartaty & Arnenda, 2019; Jatmiko et al., 2015; Mallawa et al., 2012, 2014; Nugraha & Mardlijah, 2008) and in the western Indian Ocean (Ashida et al., 2010; Grande et al., 2012, 2014; Hunter et al., 1986; Stequert & Ramcharrum, 1996).

The objective of this study was to provide information on the reproductive biology, in particular length at first maturity (Lm_{50}, size at which 50% of the individuals are mature) of female skipjack from Indian Ocean Indonesian Exclusive Economic Zone.

Materials and methods

Sample collection

Ovaries were collected from April to September 2018, and April to October 2019 from Kedonganan fishing port, Bali. A total of 230 ovaries with length ranged between 33-72 cm FL collected from handline fisheries catch. Straight fork length was measured using a measuring tape that has a precision of 1 cm. Body weight and gonad weight were recorded to the nearest gram.

Length frequency data of skipjack of gillnet, purse seine and handline was obtained from the enumeration data collected by Research Institute for Tuna Fisheries (RITF) at landing sites in southern Indonesian waters in 2018-2019.

A cross-section was removed from the middle of one ovary lobe from each fish and immediately fixed in 10% buffered formalin. Samples were embedded in paraffin and standard histological sections prepared (cut to 5 µm and stained with Harris-Haemotoxylin and Eosin). Ovarian development classification using the criteria modified by Farley et al., (2013) on South Pacific Albacore Tuna (*Thunnus alalunga*).

Histological analysis

Histological sections were classified using criteria for South Pacific albacore tuna (Farley et al., 2013). Females were classified into development stages based on the most advanced group of oocytes (MAGO), postovulatory follicles (POFs), alpha and beta atresia, and maturity

markers present in the ovary (see Table 1 for classification used). The most advanced group of oocytes (MAGO) was staged into one of 5 classes: unyolked, early yolked, advanced yolked, migratory nucleus or hydrated oocytes (Appendix 2). Each ovary was also scored based on the presence or absence of postovulatory follicles (POFs). The maturity markers considered were well defined muscle bundles, numerous brown bodies, and residual hydrated oocytes. The maturity markers are considered as signs of prior reproductive activity (Farley et al., 2016; 2013; Zischke et al., 2013).

Ovaries containing advanced yolked, migratory nucleus or hydrated oocytes and/or POFs were classed as mature, and ovaries with unyolked or early yolked oocytes as the MAGO but with maturity markers present were classed as mature as well. Ovaries containing unyolked and early yolked oocytes as the MAGO but no POFs, atresia or maturity markers were classed as immature (Farley et al., 2013).

Length at maturity (Lm_{50})

Length at 50% maturity (Lm_{50}) was estimated as the length at which 50% of the sample fish were sexually mature (Fontoura et al., 2009; Somerton, 1980). Using a Binomial logistic regression (Girault et al., 2019; Zuur et al., 2007) X is considered as the explanatory variable and the classification of sexual maturity of female skipjack (immature: 0; adult: 1) as a random variable (binomial). The mean length at which 50% of mature female were calculated using regression parameters a and b from the fitted maturity curves, with Y = 0.5 following the equation:

$$L_{50} = \frac{\left(\log\left(\frac{Y}{1-Y}\right) - a\right)}{b}$$

Results and Discussion

Length frequency distribution

The size distribution of skipjack caught by gillnet, purse seine and handline operated in southern part of Indonesian waters ranged between 27-69, 20-57, 14-79 cm FL with number of fish measured (N) were 1858, 1502, 7964 respectively (see Figure 1). A total 230 female skipjack sampled ranged between 33 – 73 cm FL for this study collected from handline catch which is represent the handline catches in Indian Ocean Indonesian Exclusive Economic Zone.

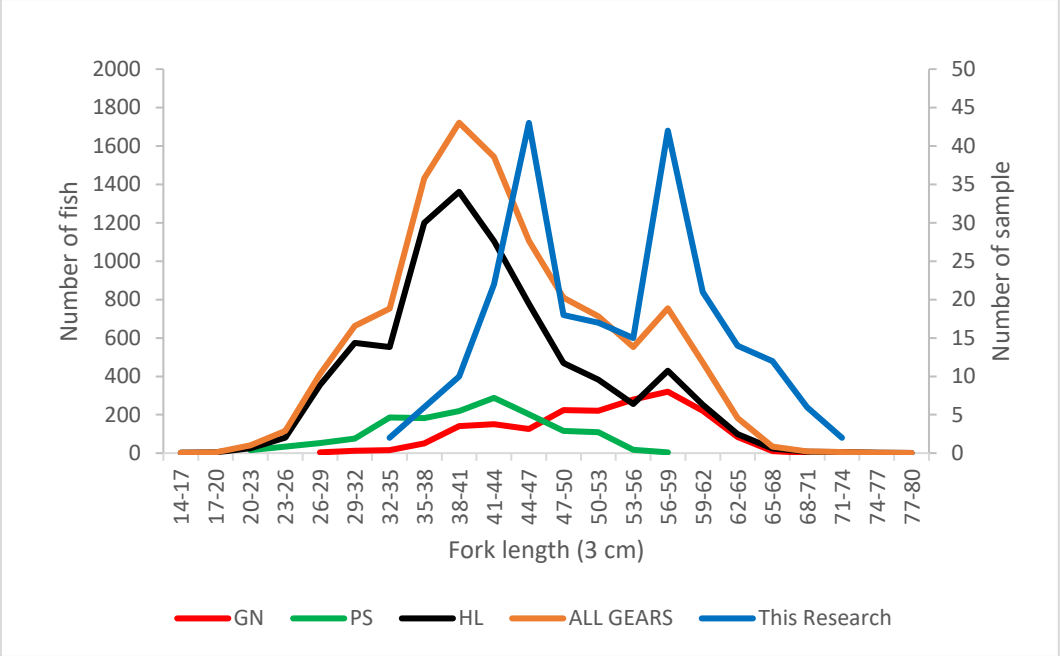

Figure 1. Size distribution of skipjack tuna caught by fishing gears operated in southern Indonesian waters (EEZ) (2018-2019). GN=gillnet; PS=purse seine; HL=handline.

Stages of oocytes development

The histological analysis of 230 ovaries of skipjack shown the asynchronic development where all oocytes stages are presented in one ovary (Grande, 2013; Murua & Saborido-Rey, 2003) (Appendix 2). Histological analysis indicated that females <46 cm FL were immature, however many females between 40 and 46 cm FL also found as mature fish and classed as either spawning capable, spawning, regressing, regressed or regenerating (Table 1). The largest immature female was 46 cm FL while the smallest spawning female was 40 cm FL.

Table 1. Summary of the histological classification of female skipjack by 3 cm FL length classes

Length (cm FL)	Immature		Mature						Total
			Active		Inactive				
	Imm	Dev	SC	Spawning	Regressing	Reg 1	Reg 2	Regenerating	
33-36	5								**5**
36-39	3								**3**
39-42	8	3	4	1				1	**17**
42-45	6	3	8	5	2	2		1	**27**
45-48	3	3	13	7		6	3	4	**39**
48-51			6	4		4	1	2	**17**
51-54			6	1	2	3	1	4	**17**
54-57			5	4	6	6	2	1	**24**
57-60			18	5	3	8	2		**36**

60-63			4	6		2	2	1	**15**
63-66			3	3	2	5	2	1	16
66-69			6	1			1		8
69-72			1		2	3			6
Total	**25**	**9**	**74**	**37**	**17**	**39**	**14**	**15**	**230**

Length at maturity (Lm_{50})

Female skipjack tuna reached maturity at 42 cm FL with the interval ranged between 41 - 42.9 cm FL (Figure 2). Using advanced yolked (AY) or Vitellogenic 3 (Vtg3) as indicator of maturity, the result of this study is similar with the previous studies in the western Indian Ocean by Stequert & Ramcharrum (1996), but slightly smaller than Grande et al. (2014); Timohina & Romanov (1996) which proposed Lm_{50} of female skipjack tuna of 42, 43.5 and 43 cm FL respectively.

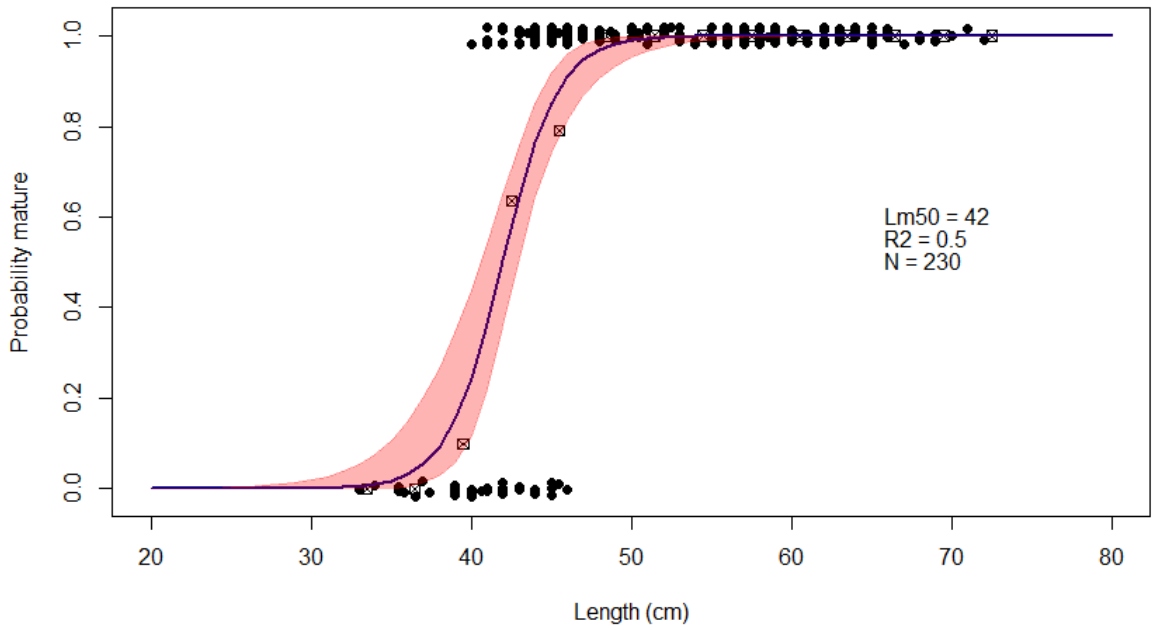

Figure 2. Curve of length at maturity (Lm_{50}) of female skipjack tuna in Indonesian Exclusive Economic Zone

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Appendix 1. Histological classification criteria based on the most advanced group of oocytes (MAGO), postovulatory follicles (POFs), atresia and maturity markers. Un = unyolked, EY = early yolked, AY = advanced yolked, Mn = migratory nucleus, Hy = hydrated.

Class	Maturity Status	Activity	Development Class	MAGO	POFs	Atresia		Maturity Marker		
						α	β	Orange/brown Bodies	Muscle Bundles	Residual Hydrated
1	Immature	Inactive	Immature	Un	No	No	No	Absent or verysmall	Absent or very small	Absent
2	Immature	Inactive	Developing	EY	No	No	No	Absent or very small	Absent or very small	Absent
3	Mature	Active	Spawning Capable	AY	No	< 50%	May be present	Maybe present	Maybe present	Maybe present
4a	Mature	Active	Spawning	AY	Yes	< 50%	May be present	Maybe present.	Maybe present	Maybe present
4b	Mature	Active	Spawning	Mn, or Hy	Possibly	< 50%	May be present	Maybe present	Maybe present	Maybe present
5	Mature	Inactive	Regressing - Potentially Reproductive	AY	No	≥50%	Present	Many, often large or in clumps	Many, often large and "folded"	Maybe present
6a	Mature	Inactive	Regressed 1	Un or EY	No	100%	May be Present	Many, often large or in clumps	Many, often large and "folded"	Maybe present
6b	Mature	Inactive	Regressed 2	Un or EY	No	No	Present	Many, smaller than class 6a	Many, smaller than class 6a	Maybe present
7	Mature	Inactive	Regenerating	Un or EY	No	No	No	Many, smaller than class 6b	Many, smaller than class 6a	Maybe present

Appendix 2. Ovaries histology cross-section of skipjack tuna in Indian Ocean Indonesian EEZ Un=unyolked; EY=early yolked; AY=advanced yolked; MN=migratory nucleus; Hy=hydrated; POF=post-ovulatory follicles; α=alpha atresia; β= beta atresia BB=brown bodies; MB=muscles bundle.