Estimating the size at sexual maturity of bigeye tuna (*Thunnus obesus*) in the eastern Indian Ocean

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Abstract

Accurate information of reproductive characteristics of bigeye tuna (*Thunnus obesus*) is an important factor in determining its regeneration capacity in a population. However, a robust analysis with proper samples representation in the eastern Indian Ocean was still limited. The study aimed to give a preliminary result on estimating size at maturity of bigeye tuna based on histological datasets from 2019-2020. A total of 78 female bigeye tuna (78-161 cm FL) were sampled from Indonesian longline fisheries and the ovaries were analyzed histologically. The estimated length at maturity (Lm50) was 101.25 cm FL at the advanced yolked stage as the threshold of maturity.

Keywords: reproductive biology, histology, bigeye tuna, eastern Indian Ocean

Introduction

Among tuna and tuna-like species, bigeye tuna (*Thunnus obesus*) is one of the most commercially important species in the Indian Ocean (Fonteneau & Pallares, 2005; Lee et al., 2005; Nugraha et al., 2010; Polacheck, 2006). They are widely distributed from tropical to subtropical waters among three major oceans, between 45^{o}N and 40^{o}S, except for the Mediterranean Sea (Collette et al., 2001). It is also the principal target species of the large longliners from Japan, China, and Taiwan and smaller longliners based in several Indian Ocean Island countries, especially Indonesia (Nootmorn, 2004).

Accurate information on the 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, an incorrect assignment can have implications for the precision and accuracy of the parameter estimates derived from these data. Microscopic/histological analysis is the most appropriate method to assess maturity status accurately and estimate reproductive parameters for tuna (Farley et al., 2013; Schaefer, 1998; Zudaire et al., 2010).

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Several studies regarding the gonad maturity level and biology reproductive of bigeye tuna using microscopic (histological) and macroscopic (visual morphology) observation methods have been carried out in the eastern (Faizah & Prisantoso, 2010; J. H. Farley et al., 2006; Nootmorn, 2004; Nugraha & Mardlijah, 2006; Suman et al., 2013) and western Indian Ocean (Ariz et al., 2006; Zhu et al., 2011).

The objective of this study was to provide information on the reproductive biology, in particular, length at first maturity (*Lm50*, size at which 50% of the individuals are mature) of female bigeye tuna from Indonesian longline tuna fleets in the Indian Ocean.

MATERIALS AND METHODS

Sample collection

A total of 78 ovaries with lengths ranged between 78-161 cm FL and weight between 9-86 kilograms were collected from the Indonesian longline fisheries based in Benoa port, Bali, and scientific observer onboard (courtesy of Research Institute for Tuna Fisheries, RITF) between January 2019 to December 2020. Straight fork length was measured using a measuring tape that has a precision of 1 cm.

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 were 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 the south Pacific albacore tuna (*Thunnus alalunga*).

Histological analysis

Histological sections were classified based on 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. The most advanced group of oocytes (MAGO) was staged into one of five classes: unyolked, early yolked, advanced yolked, migratory nucleus, or hydrated oocytes. 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; Farley et al., 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 (Lm50)

Length at 50% maturity (Lm50) was estimated as the length at which 50% of the sampled 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 bigeye tuna (immature: 0; adult: 1) as a random variable (binomial). The mean length at which 50% of mature females 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

Size at sexual maturity (Lm50)

A total of 78 histologically analyzed samples in this study were mostly mature fish (67%). The smallest mature bigeye tuna was 99 cm FL (21 kg), and the largest was 161 cm FL (86 kg). The Lm50 was estimated at 101.25 cm FL (**Fig. 1.**) for female bigeye tuna of the eastern Indian Ocean at the advanced yolked stage as the maturity threshold.

The estimated length at 50% maturity of bigeye tuna has been widely reported in the Pacific Ocean using several classification methods (macroscopic and histological analysis), Lm50 were ranged from 102-135 cm FL (Schaefer et al., 2005; Farley et al. 2006; Zhu et al. 2011; Sun et al. 2013). In the Indian Ocean, Lm50 using the macroscopic method was 88.08 cm FL (Nootmorn, 2004) and 119.5 cm FL (Zhu et al., 2011). Applying histological analysis, Zudaire et al. (2016) reported Lm50 for female bigeye tuna in the western Indian Ocean were 102 cm FL and 115 cm FL with maturity threshold at Vtg1 and Vtg3, respectively. Estimated Lm50 in our study (101.25 cm FL) was lower compared to the same method (histological analysis) on the latest study. The estimated length at maturity may vary depending on the area and/or depth sampled (Farley et al., 2006). Previous studies also found that in yellowfin tuna, the sampling depth caused the differences in maturity levels (Suzuki, 1988; McPherson, 1991). Therefore, obtaining the surface and sub-surface samples is important for maturity data analysis. The samples in the current study were only obtained from longline fisheries which operated in

the off-shore/high seas. Increasing the number of samples from both handline and longline fisheries nis needed for further studies.

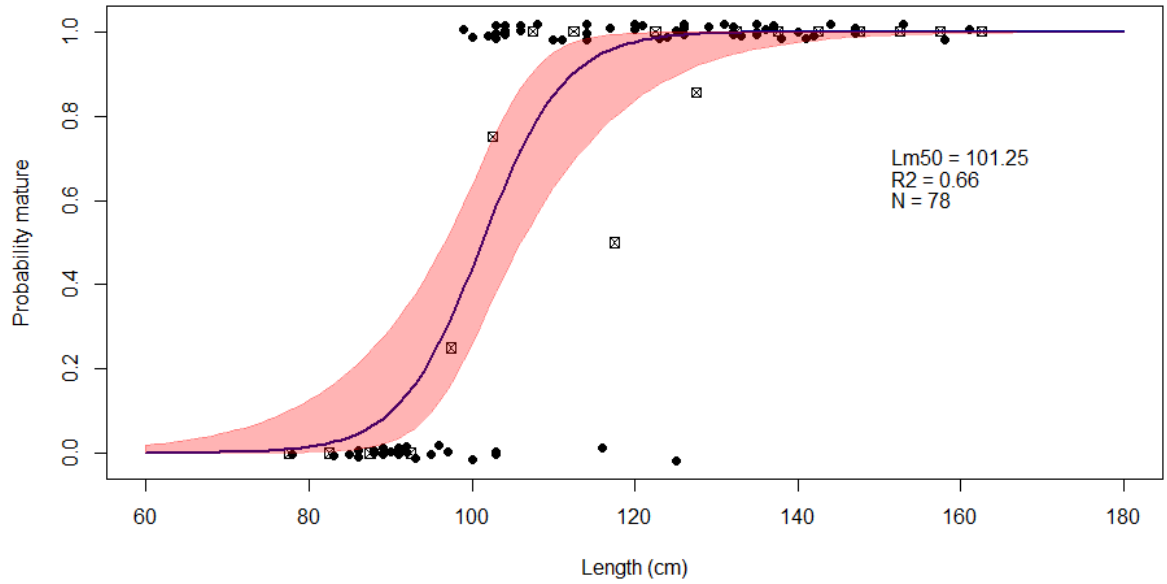

Fig 1. The estimated proportion of mature female bigeye tuna

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