Biological parameters of *Auxis* sp. in some parts of Indonesian waters

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Abstract
Neritic tuna species play a significant role in Indonesia, contributing to its economy, food security, ecosystem health, cultural heritage, and tourism industry. This study was conducted in 2019. The biological samples, including gonads and muscle tissue were collected and funded by the Ministry of Marine Affairs and Fisheries, Indonesia. Gonad maturity level was assessed morphologically. Whereas genetic analysis using the polymerase chain reaction (PCR) to amplify the samples, and electrophoresis using the QIAxcel fragment analysis tool. The results of this study showed that length at first maturity (Lm_{50}) of female bullet tuna was estimated to be 23.5 cmFL (R^2=0.5), and frigate tuna was 28.7 cmFL (R^2=0.70). The result from AMOVA analysis, there are signs of clustering of 2 subpopulations of bullet tuna, distinguished by the greatest inter-group variation values between stock groups, specifically Padang (PD) and Bengkulu (BB)-Lampung (KA) with P-value 0.0039. While frigate tuna genetic analysis discovered the presence of 2 major clusters showing the highest inter-group variation values, specifically representing the frigate tuna subpopulation, surrounding Aceh (AC), Padang (PD), and Sibolga (SB), along with Bengkulu (BB). Understanding the reproductive biology and population genetic of *Auxis* sp. is essential for fisheries management and conservation efforts. The output of the study can be used by scientists and resource managers to develop strategies to sustainably manage bullet tuna and frigate tuna populations and ensure their long-term viability.

Keywords: *Auxis* sp., biology reproduction, Indonesia, population genetic

Introduction

Neritic tuna, a small tuna group, is primarily captured in both small-scale and large-scale fisheries in Indonesia (Suryaman, 2017) play a significant role in Indonesia, contributing to its economy, food security, ecosystem health, cultural heritage, and tourism industry. Various fishing gear, including purse seines, drift gill nets, trolling lines, hand lines, and chart, are used in catching neritic tuna (Widodo et al., 2014). In Indonesia, the main types of neritic tuna caught for trade include bullet tuna (*Auxis rochei*), frigate tuna (*Auxis tazard*), and kawakawa (*Euthynnus affinis*) (Lelono & Bintoro, 2019).

The focus on this study were reproductive biology and genetic variability of bullet tuna and frigate tuna. Understanding the reproductive biology is essential for fisheries management and conservation efforts to develop strategies to sustainably manage populations and ensure their long-term viability. Whereas genetic studies can help assess the effectiveness of management measures such as size limits, fishing quotas, and spatial closures in conserving genetic diversity and preventing overexploitation.

Methods

Sampling locations

The biological samples, including gonads and muscle tissue of bullet tuna and frigate tuna (Fig. 1) were collected in 2019 and the research funded by the Ministry of Marine Affairs and Fisheries, Indonesia. The research locations were in Fisheries Management Area (FMA) 572, including Aceh, Sibolga, Padang, Lampung, and Bengkulu (Fig. 2.).

a b

Figure 1. Bullet tuna (*Auxis rochei*) (**a**); frigate tuna (*Auxis thazard*) (**b**).

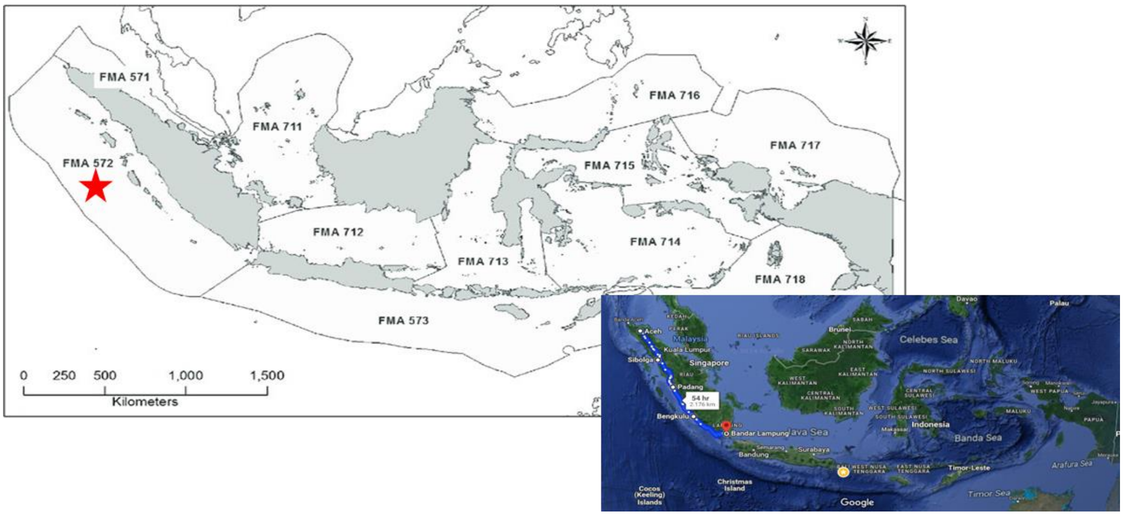

Figure 2. Fisheries Management Areas in Indonesia (Muawanah et al., 2018)

Reproduction biology

Gonad maturity level was assessed morphologically in accordance with Farley (1998) criteria, focusing on the characteristics and sizes of developing oocytes, which were categorized into the following stages: I. Unyolked stage (Undeveloped); II. Early yolked stage (In development); III. Advanced yolked stage (Initiating maturity); IV. Migratory nucleus stage (Almost mature); V. Hydrated stage (Ripe/hydrated). Gonad development also progresses to the spawning or saline stage, indicated by the presence of postovulatory follicles (POFs) and atresia. The ovaries are notably large and soft, containing clear, mature eggs that are absorbed within.

The value of the 50% gonad length of mature fish was determined using the Bayesian binomial model approach contained in the sizeMat module in R version 3.5.1 (Torrejón-Magallanes et al., 2017).

Population genetic

The DNA extraction was performed using the DNeasy Blood and Tissue Mini Kit as per the provided instructions, with subsequent measurement of DNA concentration using a nanophotometer. For low concentration samples, the extraction process would be repeated. The PCR amplification process utilized five microsatellite DNA primers and specific temperature configurations (Catanese et al., 2007). The QIAxcel fragment analysis tool assessed the band pattern data and electropherogram, enabling the identification of emerging alleles. Genetic parameters were then calculated, and the Arlequin version 3.5 program (Excoffier et al., 2005) was used to determine allele variety, population structure, and genetic diversity. Genetic distance parameters were calculated using Slatkin's method (Slatkin, 1995), and the AMOVA revealed genetic variation and population structure between population groups. GenAlEx software version 6.5 was utilized to identify the polymorphic locus (Peakall & Smouse, 2006).

Results

Bullet tuna (*Auxis rochei*)

Reproduction biology

Visual observation is used to determine the level of gonad maturity during field surveys. A total of 354 individual female samples were identified during the survey. The length at which 50% of the specimens reach maturity (Lm_{50}) was calculated using a binomial model. For female bullet tuna, the Lm_{50} value was estimated to be 23.5 cmFL (R^2=0.5), slightly higher than the previously reported value of 22.97 cmFL (R^2=0.72) (Figure 3). The Lm_{50} value from this study is lower than that found in earlier studies conducted in the waters of western Sumatra, Indonesia (Tampubolon et al., 2016), southern India (Jasmine et al., 2013), and the Mediterranean

(Kahraman et al., 2010; Macías et al., 2005), where the Lm_{50} range is reported to be between 24.63-35.00 cmFL.

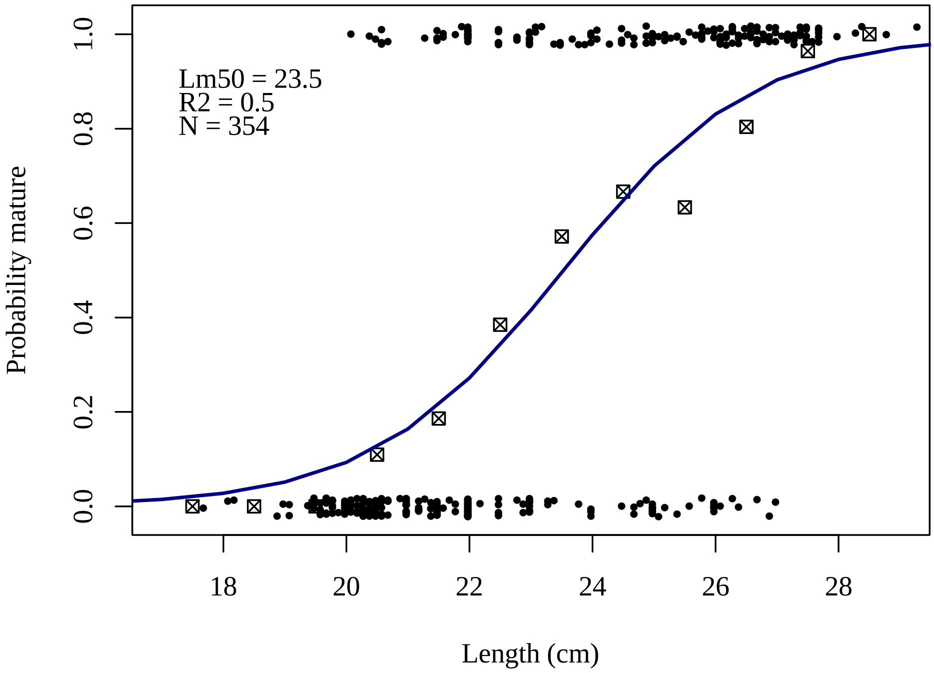

Figure 3. Length at first maturity (Lm_{50}) of female bullet tuna.

Population genetic

Tissue samples were obtained from 5 research locations, namely Aceh, Sibolga, Padang, Lampung, and Bengkulu. The total samples collected were 115 samples, with a length between 19.5-28.0 cmFL. The results of the pairwise distance test between the populations (Population Pairwise Fst) and the results of AMOVA (Analysis of Molecular Variance) calculations. The results of the F-Statistics (Fst) calculation between sample groups at all microsatellite loci use a significance value of $P<0.05$. The P value matrix obtained did not show any significant population differences, except between Padang and Lampung (Table 1).

Table 1. Fst matrix and P-values between bullet tuna population

Population	Bengkulu	Lampung	Padang
Bengkulu	-	0.4599	0.1074
Lampung	0.0007	-	**0.0039***
Padang	0.0051	0.00951	-

The result from AMOVA analysis, there are signs of clustering of 2 subpopulations of bullet tuna, distinguished by the greatest inter-group variation values between stock groups, specifically Padang (PD) and Bengkulu (BB)-Lampung (KA) (Table 2). The presence of distinct population stocks in the western Sumatran waters can be attributed to oceanographic factors like temperature, currents, and chlorophyll.

Table 2. Population structure based on differences in genetic variation in bullet tuna populations using AMOVA.

Group number	Stucture	Variation between group	% Variation	FST	P-value
2	**(PD); (BB,KA)**	**0.003**	**0.81**	**0.008**	**0.324**
2	(BB,PD); (KA)	0.001	0.23	0.045	0.659

Frigate tuna (*Auxis thazard*)

Reproduction biology

The results of the binomial model show that the length at first maturity of the gonads for female frigate tuna individuals was 28.7 cmFL, R^2=0.70, and N=256. This result is similar compared to previous research in FMA 573, with 28.38 cmFl (R^2=0.54) (Fig. 4). This value is slightly lower when compared to similar studies in Indian waters, with 29.70 cmFL (Ghosh et al., 2012) and in west of Sumatra, with 47.9 cmFL (Tampubolon et al., 2016).

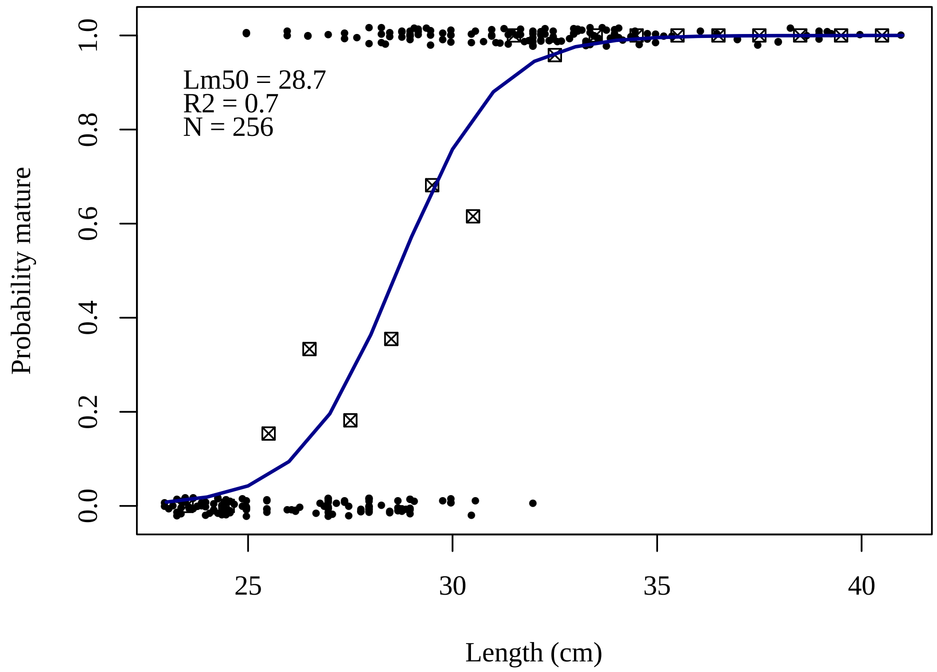

Figure 4. Length at first maturity (Lm_{50}) of female frigate tuna.

Population genetic

Frigate tuna issue samples for genetic analysis were collected at the same location as bullet tuna with total 150 samples, ranging from 17.2 cmFL to 37.0 cmFL in length. The F-Statistics (Fst) calculation results, based on a significance level of P<0.05, indicate significant different at each sampling location, as shown in the P-value matrix obtained (Table 3).

Table 3. Fst matrix and P-values between frigate tuna population

Populasi	Aceh	Bengkulu	Padang	Sibolga
Aceh		0,0107*	0,0001*	0,0039*
Bengkulu	0,0214		0,0001*	0,0001*
Padang	0,0340	0,0372		0,0001*
Sibolga	0,0208	0,0375	0,0371	

The AMOVA analysis discovered the presence of 2 major clusters showing the highest inter-group variation values, specifically representing the frigate tuna subpopulation, surrounding Aceh (AC), Padang (PD), and Sibolga (SB), along with Bengkulu (BB) (Table 3). This disparity in population is supposed from the fishing activities of the frigate tuna, with the Sibolga, Aceh, and Padang fleets primarily operating in territorial waters, while the Bengkulu fleet mainly operates near FMA 572 and 573.

Table 4. Population structure based on differences in genetic variation in frigate tuna populations using AMOVA.

Group number	**Stucture**	**Variation between group**	**% Variation**	**FST**	**P-value**
2	**(AC,PD,SB); (BB)**	**0.010**	**1.14**	**0.155**	**0.243**
3	(AC); (BB); (PD,SB)	0.008	1.00	0.152	0.510
2	(AC,PD); (BB,SB)	-0.011	-1.29	-0.012	1.000
2	(AC); (BB,PD,SB)	-0.012	-1.40	-0.014	1.000

The lack of time series data, especially regarding catch rates and length distribution, greatly hinders efforts to determine the management status of a stock. Mining secondary data, even though it must go through a long verification process, is the best alternative to support the conclusions of this research. Placing enumerators at key landing locations with the majority of purse seine fishing gear is also crucial for mapping the current condition of the bullet tuna and frigate stock.

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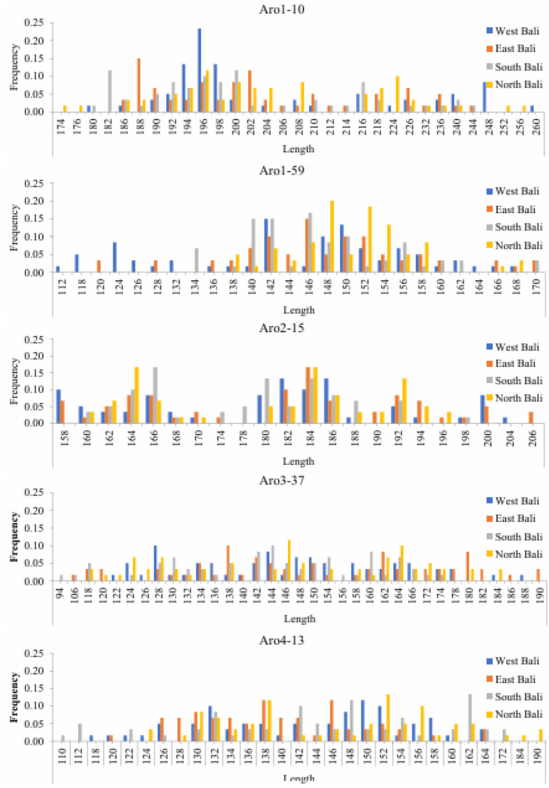
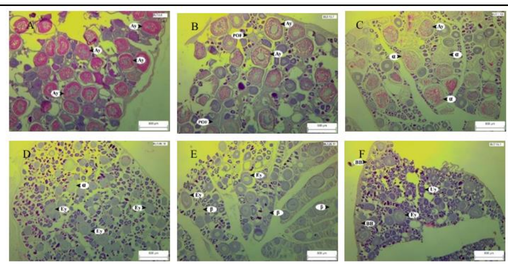
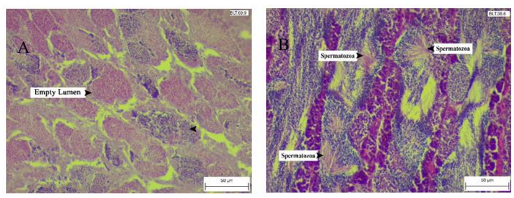
Appendix

No	Species	Year/Location	Study	Results
1	Bullet tuna	2020/Bali	Population genetic Agustina, M., Setyadji, B., Pharmawati, M., & ketut Junitha, I. (2022). Genetic Diversity and Population Structure of Bullet Tuna (Auxis rochei) from Bali and Its Adjacent Waters. *HAYATI Journal of Biosciences*, *29*(4), 507-514.	 Allele frequencies summary of bullet tuna
2	Bullet tuna	2021/Bali	Reproduction biology Pramulati, I., Hartaty, H., Sukmaningsih, A., & Sudaryanto, F. (2023). Length at first maturity and length at first capture for bullet tuna (*Auxis rochei* Risso, 1810) in the southern waters of Bali. BIO Web of Conferences.	 Gonad sections of female bullet tuna  Gonad sections of male bullet tuna