

Preliminary study of population parameters and spawning potential ratio (SPR) of yellowfin tuna (*Thunnus albacares*) in Indonesia

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Cover letter (purpose, expectation, conclusion, and recommendation)

This study aimed to estimate key biological and population parameters of yellowfin tuna, including growth parameters, mortality rates, exploitation rate, and spawning potential ratio (SPR), using length-based stock assessment approaches. These parameters provide important information for evaluating the population dynamics of yellowfin tuna in the Indian Ocean. Length-based methods are particularly useful for fisheries where detailed age-composition or long-term catch-at-age data are limited, as they allow population characteristics and stock status to be assessed from length-frequency data. The results are expected to provide scientific information to support fisheries stock assessment and the development of appropriate fisheries management measures in the Indian Ocean.

Abstract

This study evaluated the population parameters, mortality rates, exploitation, and Spawning Potential Ratio (SPR) of yellowfin tuna (*Thunnus albacares*) landed at 13 fishing ports on the Indian Ocean side of Indonesia between 2018 and 2021. A total of 87,928 specimens were measured across seven gear types, with handlines contributing the largest proportion (60.0%), followed by trolling lines (16.5%), purse seines (14.3%), and longlines (8.0%). Mean fork length varied substantially by gear, from 132.9 cm for longlines down to 34.6 cm for purse seines. Von Bertalanffy growth parameters were estimated as asymptotic length ($L_{\infty} = 212.70$ cm), growth coefficient ($K = 0.31 \text{ year}^{-1}$), and theoretical age at zero length ($t_0 = 0.82$ years). Total mortality (Z), natural mortality (M), and fishing mortality (F) were estimated at 1.65 year^{-1} , 0.49 year^{-1} , and 1.16 year^{-1} , respectively, resulting in a high exploitation rate ($E = 0.70$). Length-based SPR (LB-SPR) modeling revealed that model-estimated SPR (Ests(SPR)) remained stable between 0.30 and 0.33. However, relative fishing mortality

(Ests(F/M)) remained high (2.38–3.31), while 50% selectivity length (Ests(SL_{50})) dropped from 73.91 cm in 2018 to 54.19 cm in 2021. These findings indicate substantial fishing pressure and the need for gear-specific management.

Keywords: yellowfin tuna, population parameters, spawning potential ratio.

Introduction

Yellowfin tuna (*Thunnus albacares*) is one of the most economically and socially important tropical tuna species in Indonesia. The species supports a wide range of fisheries and provides an important source of income, employment, and food for coastal communities. In the Indian Ocean, yellowfin tuna is exploited by a diverse range of fishing fleets and gears, including handlines, purse seines, gillnets, and longlines. The Indian Ocean Tuna Commission (IOTC) identifies yellowfin tuna as one of the principal tropical tuna stocks under its mandate and regularly conducts stock assessments to support fisheries management (IOTC, 2025).

Understanding population parameters is essential for evaluating the dynamics of exploited fish populations. Growth parameters, mortality rates, and exploitation rates provide important information on the biological characteristics of a stock and the intensity of fishing pressure. The von Bertalanffy growth parameters, particularly asymptotic length (L_{∞}) and growth coefficient (K), describe the growth characteristics of a population. Mortality parameters, including total mortality (Z), natural mortality (M), and fishing mortality (F), provide information on the processes affecting population abundance (Ghosh et al., 2012).

The spawning potential ratio (SPR) is important biological indicator for assessing exploited fish populations. SPR represents the reproductive potential of a fished population relative to the reproductive potential that would be expected under unfished conditions. Length-based SPR approaches are particularly useful for fisheries where detailed age-structured data are unavailable. The LB-SPR method estimates relative fishing mortality and selectivity-at-length from the length composition of catches and life-history parameters and the spawning potential ratio (Hordyk et al., 2015).

This study aimed to estimate the population parameters, mortality rates, exploitation rate, and spawning potential ratio of yellowfin tuna landed at fishing ports on the Indian Ocean side of

Indonesia during 2018–2021 using length-based approaches. The results provide information on the biological characteristics and exploitation patterns of yellowfin tuna that can contribute to fisheries assessment and management in Indonesia.

Methods

Data collection

Data were collected from January 2018 to December 2021 at 13 fishing ports located on the Indian Ocean side of Indonesia (Figure 1). Fisheries enumerators collected information on fishing activities and biological characteristics of the catch. The information recorded by enumerators included catch, fishing effort, species, and fork length (FL).

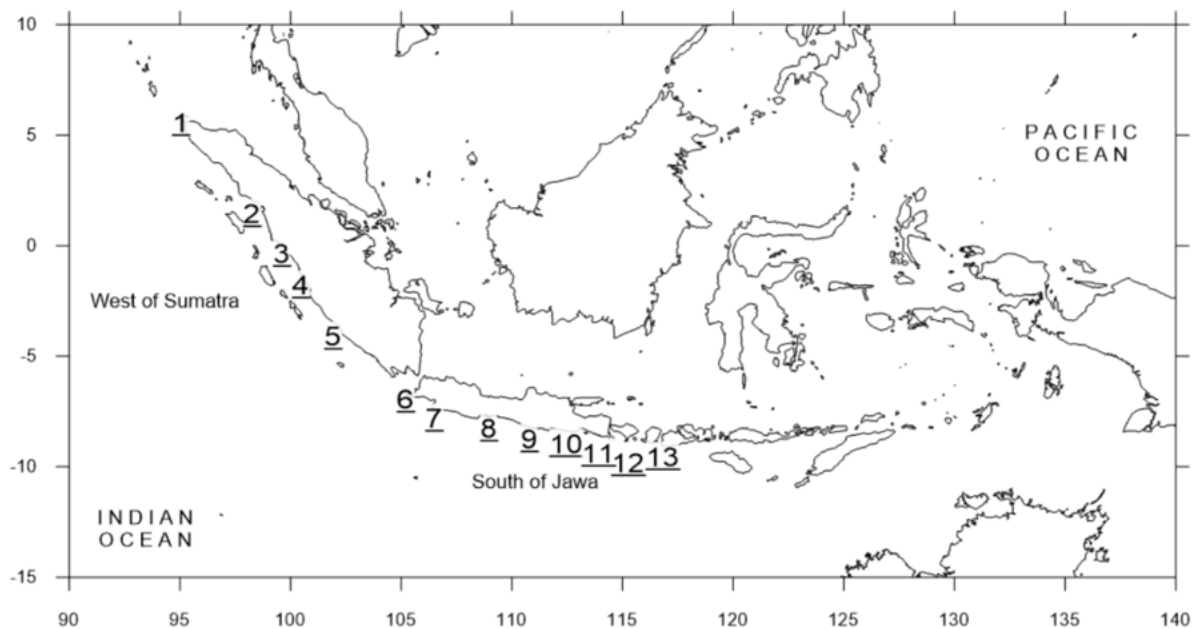


Figure 1. Data collection sites in 13 fishing ports in Indonesia: 1. Lampulo, 2. Sibolga, 3. Bungus, 4. Pasar Gaung, 5. Bengkulu, 6. Binuangeun, 7. Palabuhanratu, 8. Cilacap, 9. Pacitan, 10. Prigi, 11. Muncar, 12. Pengambangan, and 13. Labuhan Lombok.

Estimation of growth parameters

Population growth parameters were estimated using a length-based approach and the von Bertalanffy growth function (Sparre & Venema, 1998):

$$L_t = L_{\infty}[1 - \exp\{-K(t - t_0)\}]$$

where L_t is the expected fork length at age t , L_∞ is the asymptotic fork length, K is the growth coefficient, and t_0 is the theoretical age at which fish would have zero length (Pauly, 1983).

Mortality and exploitation rate

Total mortality (Z) was estimated using a length-based approach from the observed length-frequency data. Natural mortality (M) was estimated using the relationship which relates natural mortality to fish growth parameters and mean environmental temperature.

Fishing mortality (F) was estimated as:

$$F = Z - M$$

The exploitation rate (E) was calculated as:

$$E = \frac{F}{Z}$$

where Z is total mortality, M is natural mortality, and F is fishing mortality (Sparre et al., 1998).

Estimation of spawning potential ratio

The spawning potential ratio was estimated using the length-based spawning potential ratio (LB-SPR) method (Hordyk et al., 2015). The method uses the observed length composition of the catch and life-history parameters to estimate relative fishing mortality (F/M), selectivity-at-length, and spawning potential ratio. The analysis was conducted separately for each year from 2018 to 2021.

The LB-SPR analysis generated estimates of:

1. relative fishing mortality (F/M);
2. length at 50% selectivity (SL_{50});
3. length at 95% selectivity (SL_{95}); and
4. spawning potential ratio (SPR).

Results

Sample composition and length distribution

A total of 87,928 yellowfin tuna was measured during January 2018–December 2021 from 13 fishing ports on the Indian Ocean side of Indonesia. The fish were caught using seven fishing gears: handlines, trolling lines, purse seines, longlines, lift nets, gillnets, and pole-and-lines.

Handlines contributed the largest proportion of the observations, accounting for approximately 60.0% of the total samples. Trolling lines were the second-largest contributor at 16.5%, followed by purse seines at 14.3% and longlines at 8.0%. The remaining observations were obtained from lift nets, gillnets, and pole-and-lines.

The mean fork length differed considerably among fishing gears. The largest average fork length was recorded for yellowfin tuna caught by longlines, with a mean length of 132.9 cm. This was followed by fish caught using handlines (80.4 cm) and trolling lines (66.0 cm). In contrast, the smallest mean fork lengths were observed in fish caught by purse seines (34.6 cm) and lift nets (31.2 cm) (Figure 2).

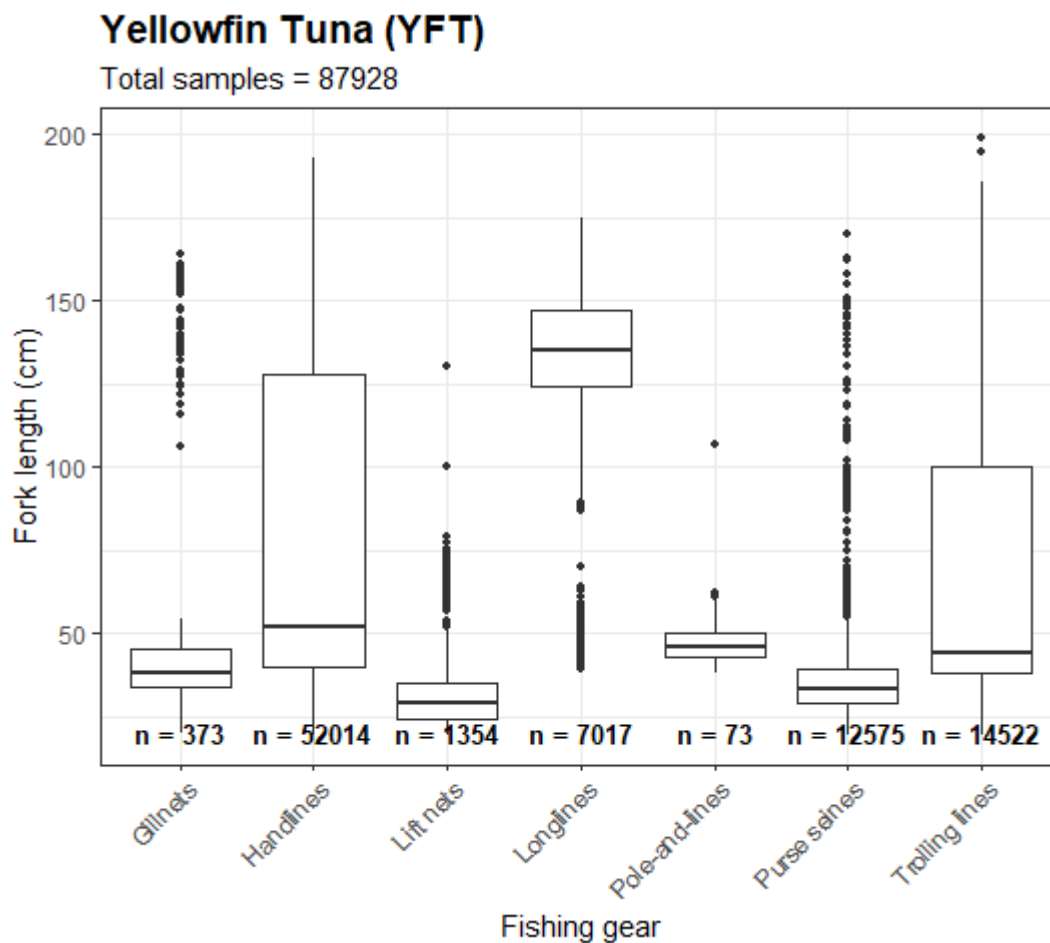


Figure 2. Length frequency of yellowfin tuna (*T. albacares*) from various gears in Indonesia.

Growth parameters

The length-based analysis estimated an asymptotic fork length (L_{∞}) of 212.70 cm, a growth coefficient (K) of 0.31 year⁻¹, and a theoretical age at zero length (t_0) of 0.82 years.

The estimated L_{∞} indicates a modeled asymptotic fork length of approximately 212.7 cm (Figure 3). The estimated K of 0.31 year⁻¹ indicates a comparatively slower approach toward asymptotic length than would be expected for a species with a higher growth coefficient. These growth parameters were subsequently used in the mortality and LB-SPR analyses.

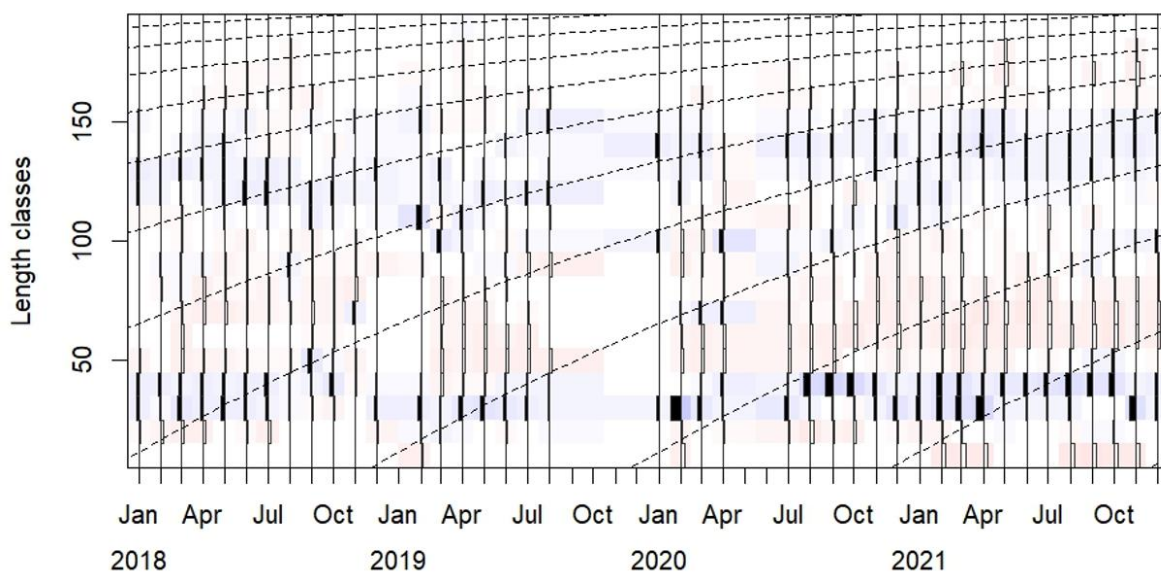


Figure 3. Monthly length frequency and Von Bertalanffy Growth Curve of yellowfin tuna (*T. albacares*) in Indonesia.

Mortality and exploitation rate

The estimated total mortality coefficient (Z) was 1.65 year⁻¹. Natural mortality estimated using the Pauly method was 0.49 year⁻¹, while fishing mortality was estimated at 1.16 year⁻¹ (Figure 4). The resulting exploitation rate was 0.70, calculated as:

$$E = \frac{1.16}{1.65} = 0.70$$

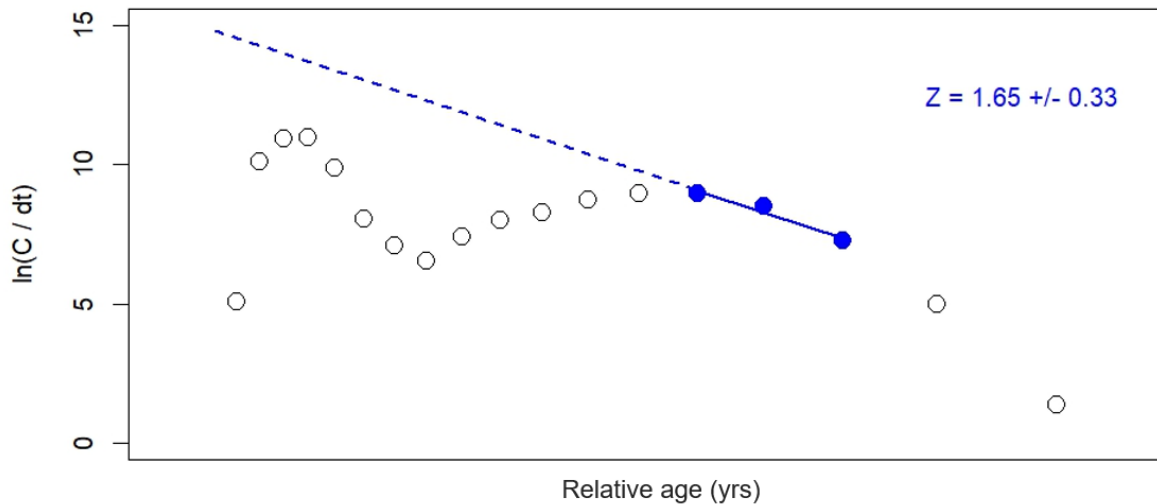


Figure 4. Length converted catch-curve (LCCC) for yellowfin tuna (*T. albacares*) in Indonesia.

Spawning potential ratio and selectivity

The LB-SPR analysis showed variation in the reported SPR output among years. The SPR values were 0.25, 0.66, 0.06, and 0.28 for 2018, 2019, 2020, and 2021, respectively. The corresponding estimated spawning potential ratios (Ests(SPR)) were 0.32, 0.33, 0.30, and 0.30, respectively. Therefore, the model-estimated SPR remained relatively stable during the study period, ranging from 0.30 to 0.33.

The estimated relative fishing mortality (Ests(FM)) was 3.31 in 2018, decreasing to 2.80 in 2019, 2.55 in 2020, and 2.38 in 2021. These values indicate that estimated fishing mortality relative to natural mortality remained above 2 during all four years, although a declining pattern was observed over the study period. The estimated length at 50% selectivity (Ests(SL50)) declined from 73.91 cm in 2018 to 54.19 cm in 2021. Similarly, the estimated length at 95% selectivity (Ests(SL95)) decreased from 102.46 cm in 2018 to 72.38 cm in 2021 (Figure 5).

The estimated Ests(SPR) decreased slightly from 0.32 in 2018 to 0.30 in 2021, while remaining within a relatively narrow range. In contrast, the raw SPR output varied substantially among years, particularly in 2020. The estimated selectivity lengths showed a clearer temporal pattern, with both SL_{50} and SL_{95} decreasing during the study period (Table 1).

Table 1. LB-SPR estimates for yellowfin tuna (*T. albacares*) during 2018–2021.

LB-SPR parameter	2018	2019	2020	2021
SPR	0.25	0.66	0.06	0.28
FM	8.47	0.19	1.75	0.66
SL50 (cm)	178.08	22.51	26.45	22.71
Ests(SL50) (cm)	73.91	63.57	57.34	54.19
Ests(SL95) (cm)	102.46	86.68	77.23	72.38
Ests(FM)	3.31	2.80	2.55	2.38
Ests(SPR)	0.32	0.33	0.30	0.30

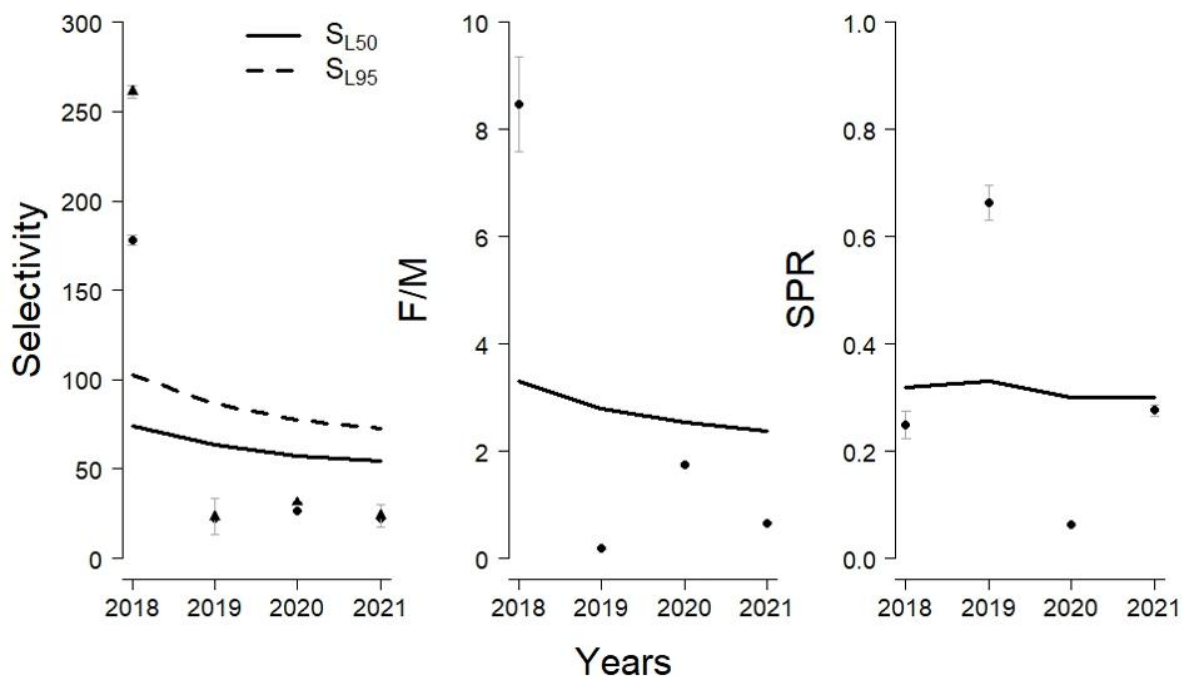


Figure 5. Yearly selectivity, F/M ratio and Spawning Potential Ratio (SPR) of yellowfin tuna (*T. albacares*) in Indonesia from 2018-2021.

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