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Growth Parameters of Yellowfin Tuna (*Thunnus albacares*) in Fisheries Management Area (WPP) 573, Southern Waters of Nusa Tenggara Barat Indonesia

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ABSTRACT: This study aimed to determine the growth parameters of yellowfin tuna (*Thunnus albacares*) in the Indonesian Fisheries Management Area (WPP) 573 in the southern waters of West Nusa Tenggara. The data consisted of primary data collected from March to June 2025 through direct measurements at UD Versace, as well as secondary data collected from July 2024 to February 2025, obtained with permission from the Masyarakat dan Perikanan Indonesia (MDPI) Foundation. The secondary data were analyzed independently by the authors, and the interpretations and conclusions presented did not necessarily reflect the institutional position of MDPI. A total of 1,027 yellowfin tuna samples were analyzed. The results showed that the yellowfin tuna caught exhibited a varied size range, with most individuals measuring between 137.74 and 145.55 cm. Most of the fish sampled had reached gonadal maturity. The length–weight relationship analysis produced the equation $W = 0.00003L^{2.8859}$, with a b value of 2.8859, indicating a negative allometric growth pattern ($b < 3$). The Von Bertalanffy growth model analysis estimated an asymptotic length (L_∞) of 193.00 cm and a theoretical age at zero length (t_0) of −0.53 years. The growth coefficient (K) was 0.34 year^{-1}, suggesting relatively rapid growth. The theoretical maximum age (t_{max}) was estimated at approximately 8.2 years. Overall, growth in yellowfin tuna was rapid during the early life stages and gradually slowed as it approached the theoretical maximum length.

KEYWORDS: *Thunnus albacares*; population dynamics; handline fishery; exploited stock; indian ocean.

1. Introduction

Yellowfin tuna (*Thunnus albacares*) was a leading commodity in the capture fisheries sector, possessing significant economic value in the global market, particularly in the Indian Ocean region. As one of the primary contributors to national production, the sustainability of tuna resources in Indonesia relied heavily on the management of Fisheries Management Area (WPP) 573, which encompassed the southern waters from Java to Nusa Tenggara. This region was characterized by high productivity and served as a key fishing ground for large pelagic species [1]. However, the open-access nature of these waters often led to high fishing pressure, necessitating strict biological monitoring to prevent stock depletion [2].

In the southern waters of West Nusa Tenggara (NTB), the yellowfin tuna fishery was predominantly driven by artisanal and semi-industrial fleets utilizing handlines. Unlike surface gears that captured a wide range of sizes, handline fisheries in the Indian Ocean specifically targeted deep-swimming, large-sized tuna to meet the stringent criteria of the export market [3]. Consequently, fishing mortality in this region was disproportionately concentrated on the adult segment of the population. While this selectivity reduced bycatch of juveniles, it posed a different risk; if the extraction of spawning-age adults exceeded the stock's regenerative capacity, it could lead to recruitment overfishing [4].

Effective management of such a heavily exploited fishery required precise biological parameters, particularly regarding growth patterns and stock conditions. Growth parameters, such as asymptotic length ($L\infty$) and growth coefficient (K), were fundamental inputs for stock assessment models. However, biological characteristics could vary significantly across different oceanic regions due to environmental factors [5]. Therefore, relying on general parameters from other regions might not accurately reflect the specific dynamics of the stock exploited in southern NTB. Understanding the specific growth dynamics of the recruited adult stock was therefore imperative to determine sustainable levels of exploitation.

Based on this urgency, this study aimed to determine the growth parameters of yellowfin tuna landed in the southern waters of NTB. By analyzing the size structure and growth dynamics of the landed catch, which represented the commercially exploited adult stock, this research provided a critical baseline for monitoring the health of the spawning cohort and formulating science-based management strategies for WPP 573.

2. Materials and Methods

2.1. Data collection.

Data collection for this study was conducted from March to June 2025 at UD Versace, one of the primary tuna collectors operating around the Labuhan Lombok Fisheries Port. This process was supported by the Masyarakat dan Perikanan Indonesia (MDPI) Foundation. The data collection site is illustrated in Figure 1. To strengthen the research findings, secondary data spanning from July 2024 to February 2025 were also incorporated, sourced from the MDPI Foundation. The secondary data were analyzed independently by the authors, and the interpretations and conclusions presented did not necessarily reflect the institutional position of MDPI. This research was conducted in several systematic phases: data collection (primary and secondary), data entry, and data processing and analysis. Primary data were collected at UD Versace from March to June 2025, while secondary data were obtained from MDPI records covering the period from July 2024 to February 2025. Subsequently, the data were tabulated using Microsoft Excel to facilitate the processing stage. The final phase involved data analysis, which was performed using the Data Analysis tool in Microsoft Excel and the ELEFAN I routine within the FiSAT II (FAO-ICLARM Fish Stock Assessment Tools) software. Yellowfin tuna samples were collected using a census method. According to [6], a census is a sampling technique in which all members of a specific population are included. In this study, the census was applied to all landed yellowfin tuna that met the criteria for large-sized fish, defined as individuals weighing ≥10 kg. The measurement recorded for each sample was fork length (FL). In addition, interviews were conducted with fishermen to determine the fishing grounds of yellowfin tuna. Respondents were selected using a purposive sampling method based on specific criteria: they had to be fishermen who caught yellowfin tuna, landed their catch at Labuhan Lombok Fishing Port, and sold it to UD Versace. A total of 14 fishermen were interviewed during the data collection period.

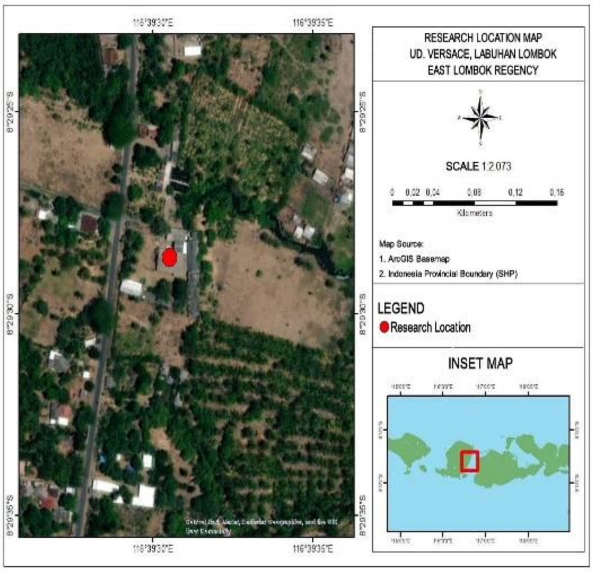

Figure 1. Data collection location.

2.2. Analysis data.

2.2.1. Morphological analysis of yellowfin tuna.

Morphology is the study of physical form and body structure to identify of fish [7]. In this study, morphological analysis was conducted by observing the characteristic features of yellowfin tuna, specifically focusing on body shape and caudal fin structure [8]. To ensure accurate identification, the morphological analysis referred to the official identification guidebooks for tuna species in Indonesia.

2.2.2. Length frequency distribution of yellowfin tuna.

In this study, the length-frequency distribution of yellowfin tuna was analyzed using the Data Analysis Tool and Histogram function in Microsoft Excel. The results were then compared with the length at first maturity (Lm) reported in previous studies. The number of classes (K) and class interval were determined using Sturges' rule as follows:

$$K = 1 + 3.32\log{(n)}$$

$$\text{Class Width} = \frac{\text{Maximum Value} - \text{Minimum Value}}{K}$$

where K is the number of classes and n is the number of observations.

2.2.3. Growth pattern analysis of yellowfin tuna.

The length–weight relationship of yellowfin tuna was analyzed to evaluate the biological condition of the fish, which is an essential aspect of fisheries resource management and biodiversity conservation [9]. In addition, this analysis was used to determine the growth pattern of the species. The length–weight relationship was expressed using the following equation [10]:

$$W = aL^b$$

where W is the total weight of fish (kg), L is fork length (cm), a is the intercept constant related to fish condition, and b is the growth exponent.

In this study, growth patterns were determined based on the value of the exponent b from the length–weight relationship, with the following criteria: (1)Positive allometric (b > 3): weight increases faster than length, (2) Negative allometric (b < 3): length increases faster than weight, and (3) Isometric (b = 3): length and weight increase proportionally.

2.2.4. Analysis of growth parameters of yellowfin tuna.

Length-frequency data of yellowfin tuna were further analyzed to estimate growth parameters using FiSAT II software through the ELEFAN I routine. Growth parameters were estimated using the von Bertalanffy Growth Function (VBGF) [11], expressed as:

$$L_t = L_\infty(1 - e^{-K(t-t_0)})$$

where Lt is fish length at age t, $L\infty$ is asymptotic length, K is the growth coefficient (per year), t is age (years), and t_0 is the theoretical age at zero length.

The theoretical age at zero length (t_0) was estimated using the empirical equation [12]:

$$\log(-t_0) = 0.3922 - 0.2752\log(L_\infty) - 1.0382\log(K)$$

The maximum theoretical age (tmax) was calculated using the formula proposed by [13]:

$$t_{max} = t_0 + \frac{2.996}{K}$$

where tmax is the maximum theoretical age, K is the growth coefficient, and t_0 is the theoretical age at zero length.

3. Results and Discussion

3.1. Length size distribution of yellowfin tuna.

This study utilized data on large yellowfin tuna (*Thunnus albacares*) collected over a one-year period from July 2024 to June 2025. Secondary data (July 2024–February 2025) were sourced from the Masyarakat dan Perikanan Indonesia (MDPI) Foundation, while primary data (March–June 2025) were obtained through direct field observations. Data gaps occurred in August 2024 and February 2025 due to limited secondary records, as well as in April 2025 due to a temporary cessation of fishing activities influenced by socio-economic factors. A total of

1,027 individuals were sampled within Fisheries Management Area (WPP) 573 in the southern waters of West Nusa Tenggara. The catch exhibited a size range of 83 to 169 cm fork length (FL), indicating a clear dominance of adult tuna.

Fluctuations in catch composition throughout the study period were closely linked to seasonal dynamics. During the peak season, catches were consistently dominated by adult yellowfin tuna, likely driven by increased availability associated with annual reproductive and migratory cycles. While [14] reported that juveniles (<50 cm) were typically prevalent during the western season (January–March), the present dataset did not reflect the presence of recruit-sized individuals. This absence was primarily attributed to the sampling criteria, which focused on individuals weighing ≥10 kg, as well as the selectivity of the fishing gear used.

The dominance of large-sized yellowfin tuna (83–169 cm) in the catch was strongly associated with the fishing techniques employed by local fishermen. Based on interviews in Labuhan Lombok, the primary method was handlining using a deep drifting technique. Fishermen operated passively by turning off the engine and using a sea anchor (parachute anchor) to stabilize the vessel's drift rate. Although Fish Aggregating Devices (FADs/Rumpon) were still present in these waters, their use had become less frequent as fishermen increasingly favored drifting techniques in open waters. This shift was strategic, as drifting with sea anchors allowed fishermen to move away from FAD structures and target deeper water columns. This method was specifically designed to access the habitat of adult tuna in the thermocline layer, effectively bypassing smaller juveniles that were typically concentrated around surface-based FADs.

Analysis of maturation levels provided further insight into the stock condition. Yellowfin tuna typically reached gonadal maturity at lengths of approximately 100–110 cm, corresponding to 2.5–3 years of age [4]. Consequently, the findings of this study indicated that the landed catch was dominated by mature individuals, which is critical for the sustainability of the spawning stock. Previous research has demonstrated that the fork length of yellowfin tuna varies significantly across Indonesian waters. In the eastern Indian Ocean, catch sizes range from 30 to 179 cm [3], whereas in the waters of Bali and Lombok, sizes range between 70 and 180 cm [15,16]. In the Banda Sea, the length range extends from 55 to 215 cm [17]. Compared to these findings, the length range obtained in this study (83-169 cm) is more concentrated within larger size classes. This distribution is influenced by oceanographic conditions, such as sea surface temperature and primary productivity, which dictate the spatial distribution of adult tuna [18]. However, the narrower size range in this study is predominantly a result of the specific market selection for export-grade tuna (≥10 kg) and the gear selectivity mentioned previously. The detailed length-frequency distribution is presented in Figure 2.

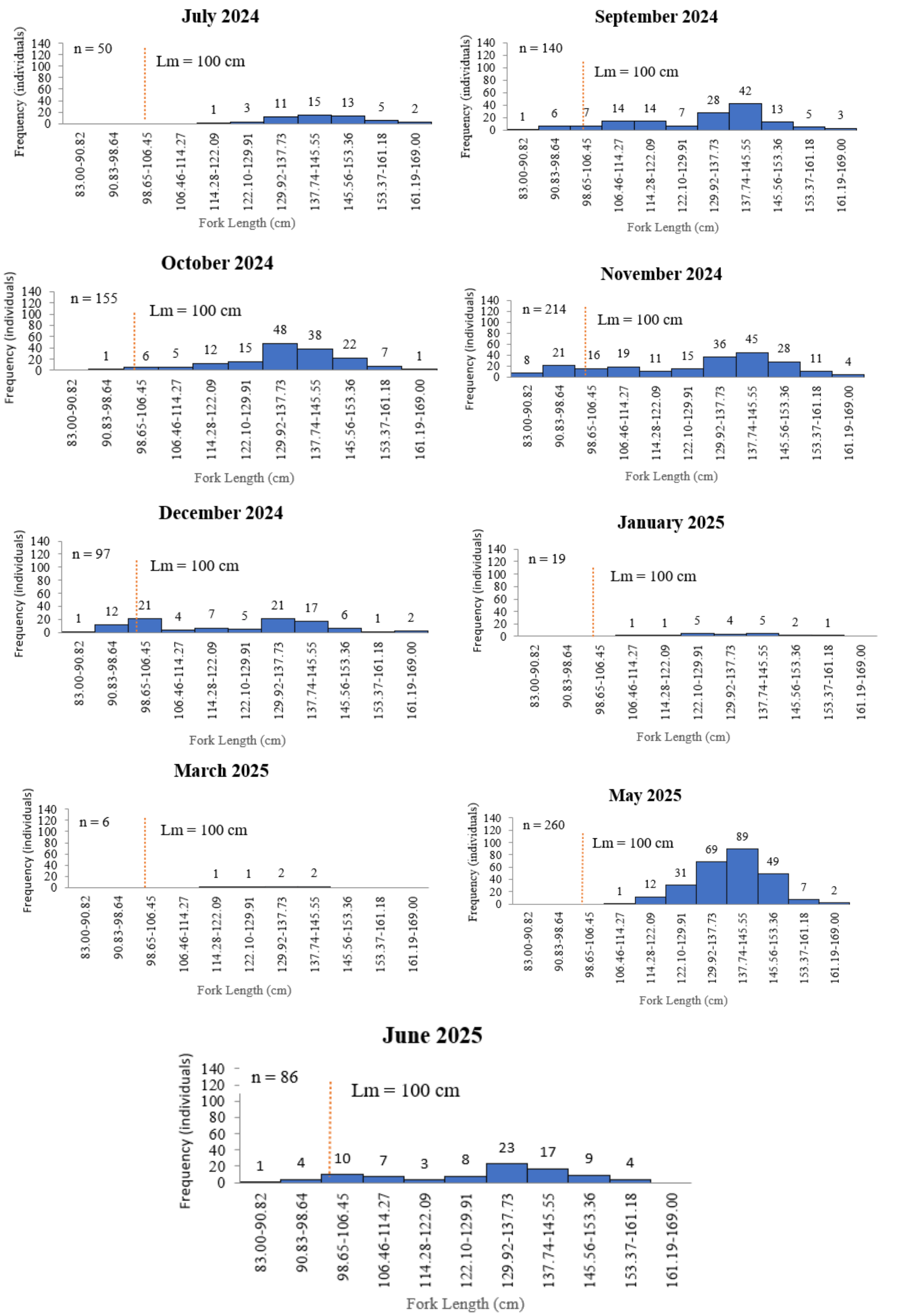

Figure 2. Distribution of length size of yellowfin tuna (≥ 10 kg) at Labuhan Lombok fishing port in July 2024-June 2025.

3.2. Analysis of yellowfin tuna growth patterns.

Based on the analysis results, the equation $W = 0.00003L^{2.8859}$ was obtained with a coefficient value of b of 2.8859 and a coefficient of determination value R^2 of 0.9618. The graph of the relationship between the length and weight of yellowfin tuna can be seen in Figure 3. Based on the analysis results, the equation $W = 0.00003L^{2.8859}$ was obtained, with a b coefficient value of 2.8859 and a coefficient of determination (R^2) of 0.9618. The graph of the relationship between length and weight of yellowfin tuna is shown in Figure 3. Based on the analysis, the growth pattern of yellowfin tuna was categorized as negative allometric ($b < 3$), with a calculated b value of 2.8859. This indicated that the increase in length occurred more rapidly than the increase in weight, resulting in a more slender body shape as the fish grew. In the context of highly migratory species such as yellowfin tuna, this slender morphology was considered an evolutionary adaptation to reduce drag and increase swimming efficiency during long-distance migrations across the Indian Ocean. A streamlined body allowed high-speed cruising and sustained energy conservation, which were critical for pursuing prey and navigating varying oceanic currents. These findings were consistent with regional studies in WPP 573 and adjacent waters. For instance, [19] reported a similar negative allometric pattern ($b = 2.8355$) at Prigi Fishing Port, while [20] observed a slightly lower b value of 2.7273 in the same management area (2017–2021). Such variations in growth parameters were common and, as noted by [21], were influenced by a complex interplay of factors including habitat conditions, diet composition, and seasonality. The b value obtained in this study reflected the specific ecological and biological dynamics of the adult stock in southern NTB. Ecologically, the negative allometric growth may have been driven by seasonal fluctuations in food availability and water temperature, which affected metabolic rates. Biologically, it suggested a shift in energy allocation. Since the sampled population was dominated by mature individuals (≥10 kg), a significant portion of somatic energy was likely diverted from somatic growth to gonadal development (reproduction) and high-intensity migratory activity, resulting in a relatively lower body mass compared to length in comparison with non-spawning populations.

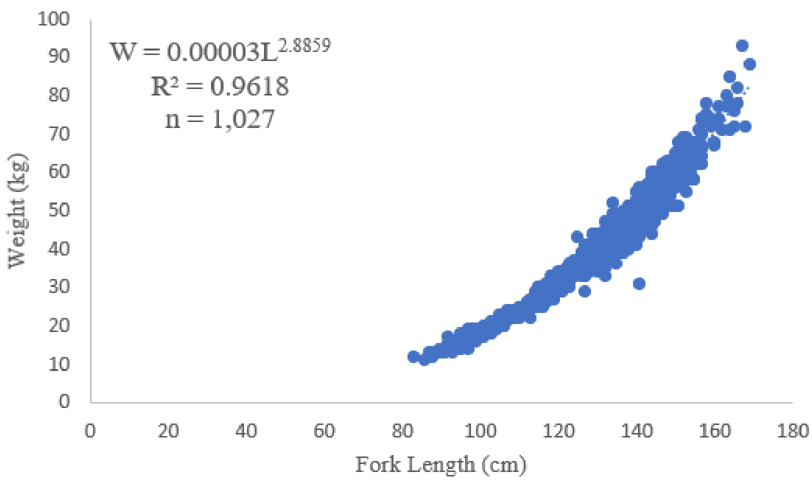

Figure 3. Length weight relationship of yellowfin tuna (≥10 kg) at Labuhan Lombok fishing port in July 2024-June 2025.

3.3. Growth analysis of yellowfin tuna.

Based on the analysis, the estimated growth parameters for yellowfin tuna were determined. The asymptotic length L_∞ was 193.00 cm, with a theoretical age at length zero t_0 of -0.53 years. The growth coefficient K was recorded at 0.34 $year^{-1}$, indicating that the yellowfin tuna in this study exhibit a relatively fast growth rate. Furthermore, the maximum theoretical age t_{max} was estimated to be approximately 8.2 years. Detailed results of these growth parameters are presented in Table 1.

Table 1. Results of yellowfin tuna growth parameters.

K ($year^{-1}$)	L_∞ (cm)	t_0 (year)	tmax (year)
0.34	193.00	-0.53	8.2

The modeled growth trajectory demonstrates that yellowfin tuna exhibit rapid somatic growth during the early life stages, specifically between ages 0 and 3 years. Beyond this period, the growth rate gradually decelerates as energy allocation shifts towards reproduction and the fish approaches its asymptotic size L_∞. This pattern reflects the typical sigmoidal growth curve of large pelagic species in tropical waters. The visualization of this growth progression is provided in Figure 4.

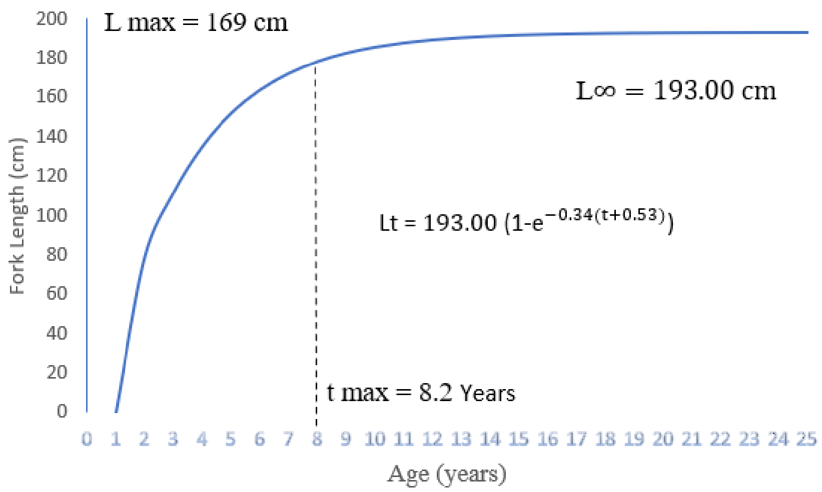

Figure 4. Growth curve of yellowfin tuna (≥10 kg) at Labuhan Lombok fishing port.

The calculated growth curve is consistent with the output generated through the FiSAT II software modeling (Figure 5). The strong alignment between the observed size at age data and the model suggests that the Von Bertalanffy function provides a robust fit for describing the growth dynamics of the exploited stock in this region.

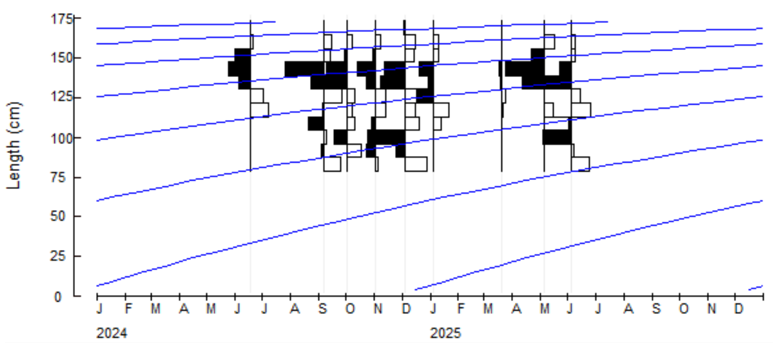

Figure 5. Von Bertalanffy growth plot (ELEFAN I) of yellowfin tuna at Labuhan Lombok fishing port.

Comparison with previous studies revealed spatial variations in growth parameters across the Indian Ocean. The $L\infty$ obtained in this study (193.00 cm) was closely aligned with recent findings by [22,23], who reported values of 194.25 cm. However, it was slightly higher than values reported by [24,25] from Pelabuhan Ratu (178 cm). Conversely, [20] reported a significantly larger $L\infty$ of 204 cm but with a slower growth coefficient ($K = 0.18$ year^{-1}). A notable outlier was the study by [26] in West Aceh, which reported a much lower $L\infty$ of 97.65 cm. This discrepancy likely reflected a sampled population dominated by juvenile individuals due to different gear selectivity, whereas the current study targeted the adult stock.

These variations confirmed that yellowfin tuna growth is highly plastic and influenced by regional environmental characteristics. As noted by [26], factors such as food availability, habitat suitability, and oceanographic variables (temperature, salinity, and currents) played a decisive role. Ocean current dynamics were particularly critical as they influenced larval dispersal and the distribution of productive feeding grounds [27, 28]. Ultimately, the interplay between intrinsic factors (genetics and age) and extrinsic variables (seasonality and dissolved oxygen) shaped the unique growth profile of this population [5].

4. Conclusion

The results confirmed that yellowfin tuna (*Thunnus albacares*) landed in the study area represented a predominantly exploited adult stock, characterized by a size range mainly between 137.74 and 145.55 cm. Consequently, most sampled individuals had reached gonadal maturity. The length–weight relationship followed the equation $W = 0.00003L^{2.8859}$ ($b = 2.8859$), indicating a negative allometric growth pattern. Furthermore, the von Bertalanffy growth model estimated an asymptotic length ($L\infty$) of 193.00 cm, a growth coefficient (K) of 0.34 year^{-1}, and a theoretical age at zero length (t_0) of −0.53 years. These parameters reflected a relatively fast growth rate for the adult population, with a maximum theoretical age (tmax) of approximately 8.2 years. The dominance of large-sized individuals was primarily driven by a strategic shift in fishing practices among local fishermen in Labuhan Lombok. The increasing preference for deep drifting techniques using sea anchors, combined with reduced reliance on surface-based Fish Aggregating Devices (FADs or rumpon), enabled more selective targeting of adult tuna in deeper thermocline layers. This technical selectivity, together with seasonal fishing patterns that coincided with adult migratory movements, effectively reduced the capture of juvenile stocks. Overall, this biological profile provides an important reference for the adult stock and is essential for assessing reproductive resilience and preventing growth overfishing in the intensively exploited waters of WPP 573.

Author Contribution

Murniati contributed to conceptualization, methodology (growth modeling and sampling design), formal analysis (parameter calculation), investigation (field sampling at UD Versace), and writing the original draft. Ayu Adhita Damayanti contributed to supervision, validation of biological data, and writing, review, and editing of the manuscript. Soraya Gigentika contributed to supervision, methodology, and writing, review, and editing. Amrollah contributed to resources (provision of MDPI datasets) and data curation. Muhammad Taeran contributed to investigation (field coordination) and resources.

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