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MORPHOMETRIC ANALYSIS OF INDIAN MACKEREL (*Rastrelliger kanagurta*) LANDED IN KUPANG IN OCTOBER AND NOVEMBER: LENGTH RATIO AND LINEAR RELATIONSHIP OF TL-FL-SL

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Abstract - *This study was conducted to analyze the morphometric characteristics of Indian mackerel (Rastrelliger kanagurta) landed in Kupang during October – November 2025. Morphometric analysis was performed as body-length parameters constitute fundamental biological indicators for assessing growth patterns, detecting variations in body form, and generating essential size-conversion metrics that support population biology and stock-management assessments. A total of 303 individuals were measured for Total Length (TL), Fork Length (FL), and Standard Length (SL) to analyze size distribution, analyze length ratios (FL/TL, SL/TL, SL/FL), and analyze linear relationships between parameters using linear regression and two-way ANOVA to test the effects of size class and ratio type. The size distribution indicated that TL ranged from 21.0 to 32.1 cm (mean = 25.708 ± 3.601 cm), with FL ranging from 19.0 to 29.1 cm and SL ranging from 17.7 to 26.5 cm. Length ratios were relatively stable in small to medium size but decreased in larger individuals, suggesting disproportionate length growth. The ANOVA results revealed significant effects of size class and ratio type on body-length ratios (p < 0.05). Linear relationships between the length parameters exhibited a negative allometric growth pattern (b < 1), accompanied by extremely high correlation coefficients (r = 0.998 for TL-FL, TL-SL, and FL-SL), indicating that FL and SL increased proportionally more slowly than TL.*

Keywords: *indian mackerel, morphometry, length ratio, negative allometry, Kupang*

I. INTRODUCTION

The Indian mackerel (*Rastrelliger kanagurta*) is one of the small pelagic species that serves an important role in the productivity of capture fisheries in Indonesia, including the waters of East Nusa Tenggara. According to marine fisheries production statistics for Kupang, the production of Indian mackerel reached 1,205.56 tons or 6.19% of the total marine fish production in 2023 (BPS Kota Kupang, 2024). This production level is relatively high compared to several other species, although still lower than the production of snapper (11.08%), trevally (7.43%), scad (6.31%), and skipjack tuna (6.25%).

The high productivity of this species highlights its economic importance, thereby emphasizing the need for scientific information on its biological condition in the waters. Various approaches have been developed to assess the status of fishery resources, including population dynamics analyses that assess growth patterns and size structure.

Beverton and Holt, in their classic work *On the Dynamics of Exploited Fish Populations* (1957), emphasized that biological data are essential for evaluating stock status and the sustainability of fishing activities (Badrudin, 2013). In this context, analyses of relationships between length parameters (and weight) and body-size ratios constitute fundamental approaches in fish biology, contributing to the estimation of growth models and the identification of morphological changes across life stages (Froese, 2006; Pol *et al*., 2011).

Growth characteristics and size structure within a population are influenced by environmental conditions, seasonal dynamics, and fishing pressure. Studies on Indian and short mackerel across different regions report unimodal or bimodal size distributions, indicating the influence of cohort composition, migration patterns, and variability in recruitment (Kasmi *et al*., 2017; Caesario *et al*., 2022; Hidayat *et al*., 2024; Putri *et al*., 2024). These patterns demonstrate that morphometric traits of mackerel

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vary among regions, each characterized by specific habitat conditions. According to Fisher *et al.* (2022), variations in body proportions (and fin surface area) can affect swimming performance and survival, particularly during early life stages. This indicates that morphometric assessment provides not only insights into population size structure but also a functional basis for understanding ecological adaptation in fish.

Fish morphometrics, which involve proportional relationships among body parts such as Total Length (TL), Fork Length (FL), and Standard Length (SL), serve as essential tools for understanding growth patterns and changes in body form. Linear relationships between these length parameters can be used to determine whether growth is isometric or allometric, whereas length-ratio analysis enables more detailed evaluation of proportional changes that may be related to ecological strategies, swimming efficiency, or physiological adaptations (Froese, 2006; Pauly, 1984).

Although several studies on the morphometrics of Indian mackerel have been conducted in various regions of Indonesia, similar investigations in Kupang remain limited, particularly those analyzing length ratios, proportional changes across size classes, and linear relationships between TL, FL, and SL. Therefore, this study aims to: (1) analyze the size distribution of Indian mackerel during October – November; (2) analyze length ratios and their variations across size classes; and (3) analyze the linear relationships between TL, FL, and SL to determine growth patterns and morphometric characteristics. The findings of this study are expected to support population biology assessments and provide a scientific basis for sustainable management of Indian mackerel fisheries in Kupang and its surrounding waters.

II. METHODOLOGY

The study was conducted from October to November 2025 by recording and measuring purse-seine catches landed in Kupang, East Nusa Tenggara, Indonesia. A total of 303 Indian mackerel specimens were collected, consisting of 157 individuals in October and 146 individuals in November.

Morphometric measurements of Indian mackerel followed standard procedures for Total Length (TL), Fork Length (FL), and Standard Length (SL), using a measuring board with 0.1 cm precision. TL was measured from the tip of the snout to the end of the caudal fin (cm); FL from the tip of the snout to the fork of the caudal fin (cm); and SL from the tip of the snout to the base of the caudal fin (cm).

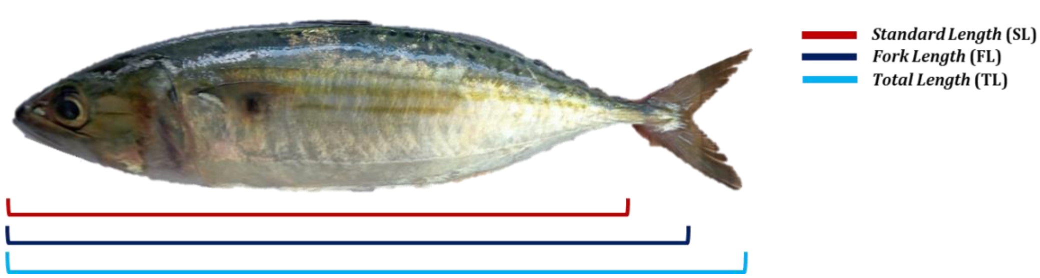

Figure 1. Measurement of TL, FL, and SL

The size distribution of Indian mackerel was analyzed using descriptive statistics, including minimum (Min), maximum (Max), mean (Mean), range, and standard deviation (SD). These values were generated using the Descriptive Statistics function in Microsoft Excel. Total length (TL) data were then presented in a histogram to illustrate the population size structure.

Length-ratio analysis was conducted to evaluate changes in body proportions across size increments by calculating three ratios: (1) Fork Length to Total Length (FL/TL); (2) Standard Length to Total Length

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(SL/TL); and (3) Standard Length to Fork Length (SL/FL). Ratio values were expressed as percentages (%) for each size class using the following equation:

Ratio = (Body-part length / Reference length) x 100

This proportional approach was used to evaluate relative changes in body form across size classes, conceptually linked to the principles of allometry in fish growth analysis (Froese, 2006).

To assess the effects of size class and ratio type on body-length ratios, a two-way ANOVA was applied. In this analysis, the first factor was size class (rows) and the second factor was ratio type (FL/TL, SL/TL, and SL/FL) (columns). Statistical significance was tested at the 95% confidence level ($\alpha = 0.05$), and differences were considered significant when $F_{calculated} > F_{critical}$. The statistical procedure followed the principles of variance analysis in biostatistics (Zar, 2010). All analyses were performed using Microsoft Excel.

Further analysis was conducted to analyze changes in length ratios across size classes to identify patterns in proportional body-form variation. Ratio changes were calculated using the equation:

$$\Delta \mathbf{R} = \mathbf{R_i} - \mathbf{R_{i+1}}$$

Where ΔR represents the change in ratio, R_i denotes the ratio in the lower size class, and R_{i+1} denotes the ratio in the higher size class. This approach describes the dynamics of proportional body-form changes between size classes and is conceptually aligned with size-structure analysis in fish population dynamics (Pauly, 1984).

Relationships between length parameters were analyzed using simple linear regression following Kara *et al.* (2020) and Naserabad *et al.* (2022), using the general equation $y = a + bx$ or its logarithmic form $\log(y) = a + b \log(x)$, where a is the intercept, b is the regression slope, x is the independent (predictor) variable, and y is the dependent variable.

The strength of the relationships was assessed using the correlation coefficient (r), while the coefficient of determination (R^2) was used to quantify the contribution of x to y. A t-test was applied to evaluate whether the slope b significantly differed from 1, with the following criteria: (1) $b = 1$: isometric growth; (2) $b < 1$: negative allometric growth; and (3) $b > 1$: positive allometric growth. Statistical significance was tested at the 95% confidence level ($\alpha = 0.05$) by comparing $t_{calculated}$ to $t_{critical}$.

Selection of the independent (x) and dependent (y) variables was based on two considerations: (1) the predictive role of the variable, in which the independent variable is assumed to explain or influence variation in the dependent variable; and (2) the inclusiveness of measurement, where the independent variable represents a larger morphometric unit encompassing the dependent variable. Accordingly, TL was designated as the independent variable because it reflects overall fish growth, whereas FL and SL represent proportional components derived from TL. This causal direction is widely applied in length-conversion modeling in fish biology (Pol *et al*., 2011). Thus, increases in TL are assumed to drive corresponding changes in FL and SL. Additionally, FL was treated as the independent variable when analyzing its relationship with SL, because FL morphometrically includes SL and can functionally account for variation in SL as the smallest length unit. This approach is consistent with principles of fish morphometrics and common practice in length-length relationship analysis (Kara *et al*., 2020; Naserabad *et al*., 2022).

III. RESULTS AND DISCUSSION

3.1 Size Distribution

The results showed that the Indian mackerel caught during October and November had TL ranging from 21.0 to 32.1 cm, with FL ranging from 19.0 to 29.1 cm and SL ranging from 17.7 to 26.5 cm. The overall TL distribution represented a combination of the October TL range (21.2 – 32.1 cm) and the November TL range (21.0 – 30.6 cm). The total TL range obtained was 11.1 cm, with a mean TL of 25.708 cm (SD ± 3.601)

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Table 1. Descriptive statistics of length distribution of Indian mackerel

Item	October			November			Total		
	TL (cm)	FL (cm)	SL (cm)	TL (cm)	FL (cm)	SL (cm)	TL (cm)	FL (cm)	SL (cm)
Mean	24.964	22.685	20.868	26.509	24.165	22.144	25.708	23.398	21.483
SD	3.824	3.372	2.908	3.166	2.801	2.541	3.601	3.192	2.806
Min	21.2	19.0	17.8	21.0	19.3	17.7	21.0	19.0	17.7
Max	32.1	29.1	26.5	30.6	27.7	25.5	32.1	29.1	26.5
Range	10.9	10.1	8.7	9.6	8.4	7.8	11.1	10.1	8.8

The length-frequency distribution obtained in this study differs somewhat from the records reported by Putri *et al.* (2024) for Indian mackerel landed in Tanjung Luar, East Lombok. The study documented TL range of 13.2 – 30.4 cm (mean 22.07 ± 4.68 cm), FL range of 12.5 – 28.2 cm (mean 20.35 ± 4.45 cm), and SL range of 11.3 – 25.7 cm (mean 18.75 ± 3.90 cm). The differences are primarily attributable to the wider range reported by Putri *et al.* (2024), which included smaller individuals than those recorded in the present study, resulting in a lower mean size.

The length distribution of Indian mackerel obtained in this study is illustrated in a histogram of 12 TL size classes (Figure 2). Each size class exhibited varying frequencies, with the highest frequency observed in the 22 – 22.9 cm class (62 individuals), and the lowest in the 31 – 31.9 cm and 32 – 32.9 cm classes (10 individuals each). No individuals were recorded in the 24 – 24.9 cm and 25 – 25.9 cm classes during October and November, indicating that only 10 size classes effectively characterized the length distribution during the study period.

The size distribution observed in this study displays an asymmetric pattern with indications of bimodality. The frequency of individuals increases at intermediate length classes before declining, and subsequently rises again in the larger size classes. This distribution pattern suggests that the size structure of Indian mackerel during October and November was characterized by the presence of two distinct size groups or cohorts within the population.

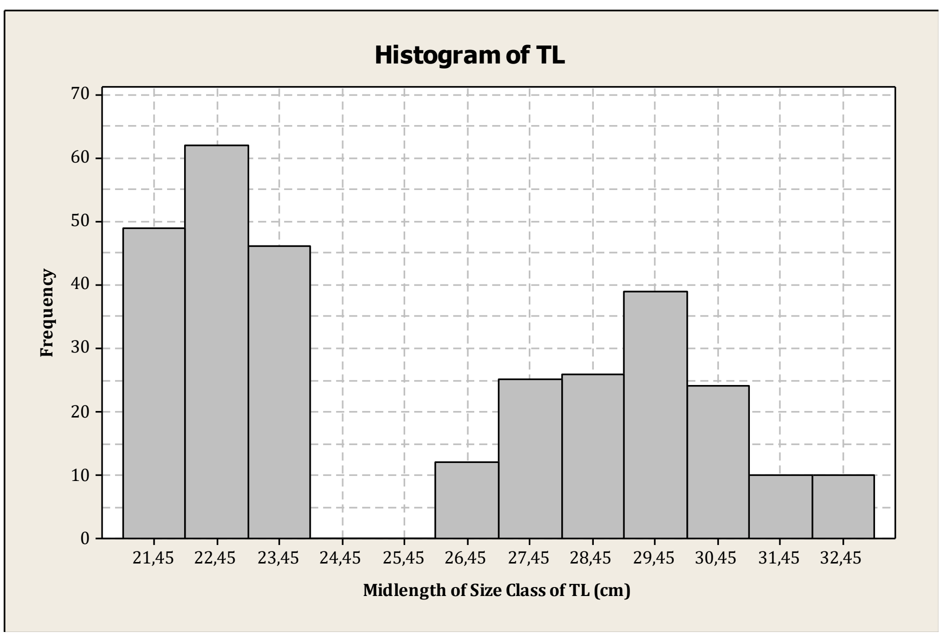

Figure 2. Histogram of TL distribution of indian mackerel

Putri *et al.* (2024) reported a size distribution of Indian mackerel that tends to exhibit a bimodal pattern, whereas Hidayat *et al.* (2024) found that the size distribution of short mackerel in northern Java waters appears predominantly unimodal, although neither study explicitly stated this. Such variation

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represents a common phenomenon, indicating that size distribution patterns in fish populations are influenced by multiple factors. These may include spatial and temporal differences in sampling or fishing activities, size-specific migratory movements related to spawning, monthly differences in growth rates driven by habitat variability, the entry of new size groups into the population, or the dominance of particular size classes associated with fishing pressure that shapes population size structure (Caesario *et al*., 2022; Kasmi *et al*., 2017; Lorenzen, 2005; Lowerre-Barbieri *et al*., 2011; Pauly, 1984).

3.2 Length-Size Ratios

The length ratios between FL and TL (FL/TL), SL and TL (SL/TL), and SL and FL (SL/FL) exhibit a clear pattern of variation with increasing size classes of Indian mackerel. Within the 21.0 – 21.9 cm to 23.0 – 23.9 cm size classes, the FL/TL ratio remains relatively high and stable, ranging from 91.041% to 91.457%. The SL/TL ratio ranges from 84.312% to 84.384%, while the SL/FL ratio ranges from 92.247% to 92.614%. These values indicate that within this size interval, the proportional changes in body dimensions remain relatively uniform.

In the larger size classes (26.0 – 26.9 cm to 32.0 – 32.9 cm), all length-size ratios show a steady decline. The FL/TL ratio decreases from 91.345% in the 26.0 – 26.9 cm size class to 89.701% in the 32.0 – 32.9 cm class. A more pronounced decline is observed in the SL/TL ratio, which drops from 83.780% to 81.617% across the same size range. The SL/FL ratio also follows a decreasing pattern, shifting from 91.718% to 90.945 – 90.995% in the largest size classes.

Table 2. Distribution of length-ratio percentages of indian mackerel

Size Class	Length-Ratio Percentages (%)		
	FL/TL	SL/TL	SL/FL
21 – 21.9	91.041	84.312	92.614
22 – 22.9	91.446	84.352	92.247
23 – 23.9	91.457	84.384	92.270
24 – 24.9	0	0	0
25 – 25.9	0	0	0
26 – 26.9	91.345	83.780	91.718
27 – 27.9	91.055	83.456	91.654
28 – 28.9	90.983	83.313	91.572
29 – 29.9	90.928	83.035	91.320
30 – 30.9	90.451	82.416	91.115
31 – 31.9	90.096	81.937	90.945
32 – 32.9	89.701	81.617	90.995

The percentage length ratios obtained in this study are generally consistent with values reported by FishBase for *R. kanagurta*, where the SL to TL ratio is 86.9% and the FL to TL ratio is 90.0%. This similarity suggests that the morphometric characteristics of indian mackerel are relatively stable across different regions, including the waters surrounding Kupang.

The variation in length-ratio percentages was further evaluated using a two-way ANOVA. The results showed that both size class and ratio type had significant effects on the length ratios ($p < 0.05$). The size class factor produced $F_{calculated}$ of 1070.943, which was greater than the $F_{critical}$ of 2.259. This finding indicates that the length ratios differed significantly among size classes, demonstrating that increases in body length are accompanied by corresponding changes in body proportions.

The ratio type (FL/TL, SL/TL, and SL/FL) also exhibited a similar pattern, as indicated by the $F_{calculated}$ (53.587), which was greater than the $F_{critical}$ (3.44). This result demonstrates that the three ratios differ significantly from one another, suggesting that each ratio represents distinct aspects of body-part growth.

To further substantiate the findings of the length-ratio analysis, changes in ratio values across size classes were calculated. As illustrated in the graph (Figure 3), the length-ratio dynamics show that all

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three morphometric ratios (FL/TL, SL/TL, and SL/FL) fluctuate with increasing size class. These fluctuations generally display negative values in the medium to larger size classes, indicating proportional reductions in certain body measurements as body length increases.

In the 21.0 – 21.9 cm and 22.0 – 22.9 cm size classes, the ratios still exhibit relatively high changes, with values of 0.0040 for FL/TL, 0.0004 for SL/TL, and -0.0037 for SL/FL. Between the 22.0 – 22.9 cm and 23.0 – 23.9 cm size classes, the magnitude of ratio change begins to decline (0.0001 for FL/TL and 0.0003 for SL/TL), except for SL/FL, which shows a slight increase (0.0002) relative to the previous class.

Entering the larger size classes (26.0 – 26.9 cm to 29.0 – 29.9 cm), all ratios show negative values (-0.0006 to -0.0029 for FL/TL, -0.0014 to -0.0032 for SL/TL, and -0.0006 to -0.0025 for SL/FL). This indicates that the increase in body components (FL and SL) occurs at a slower rate than the increase in reference length (TL or FL). The most pronounced decline is observed in the SL/TL ratio, suggesting that the growth of the main body segment (standard length) becomes increasingly lagged relative to total body growth, consistent with the percentage-ratio patterns described earlier.

In the 30.0 – 30.9 cm to 32.0 – 32.9 cm size classes, the ratios remain negative and relatively consistent, except for SL/FL, which shifts to a positive value (0.0005) in the largest size class. This pattern reinforces that increases in caudal length become more dominant than growth of the main body axis, particularly in larger individuals.

Overall, the pattern of ratio change reflects non-proportional, or allometric, growth. Smaller fish exhibit relatively balanced growth among body components, whereas larger fish show a shift in body proportions toward a more elongated form. Such changes are linked to functional adaptation across life stages: younger fish maintain more proportional body dimensions to support rapid somatic growth, while adults develop a more elongated body form to enhance swimming efficiency and migratory performance (Froese, 2006).

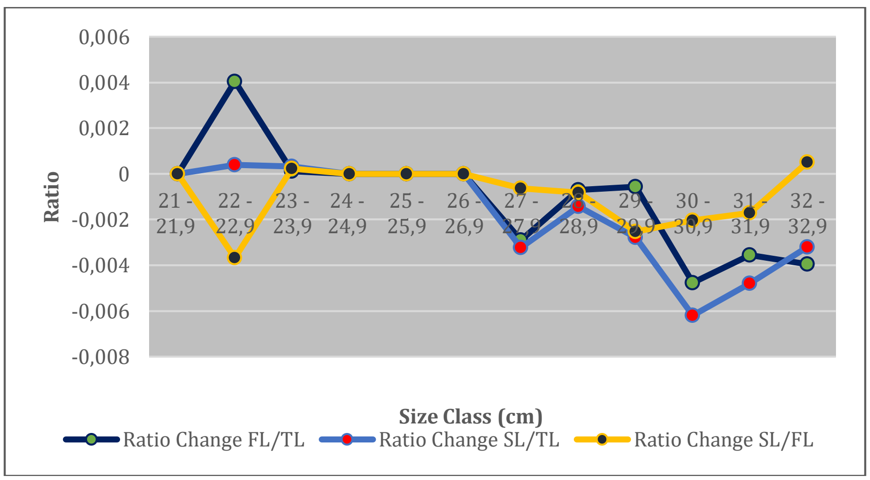

Figure 3. Trends in length-ratio changes of indian mackerel

3.3 Linear Relationships Between TL, FL, and SL

Simple linear regression analysis revealed very strong relationships between TL, FL, and SL of indian mackerel. The TL-FL relationship is expressed by the logarithmic form as log FL = -0.006 + 0.975 log TL, with a correlation coefficient of r = 0.998, indicating a very strong positive relationship between the two variables, meaning that increases in TL are accompanied by corresponding increases in FL. The coefficient of determination (R^2 = 0.997) suggests that 99.7% of the variation in FL is explained by TL.

The TL-SL relationship shows a similar pattern, expressed by the logarithmic form as log SL = 0.016 + 0.934 log TL, with a correlation coefficient of r = 0.998, also indicating a very strong positive relationship, where increases in TL are linearly associated with increases in SL. The high coefficient of determination (R^2 = 0.996) indicates that 99.6% of SL variation is explained by TL.

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The FL-SL relationship is described by the logarithmic form as log SL = 0.024 + 0.956 log FL, with a correlation coefficient of r = 0.998 and a coefficient of determination (R^2 = 0.996), demonstrating a very strong positive association, meaning that increases in FL are accompanied by increases in SL, with FL accounting for 99.6% of the variation in SL

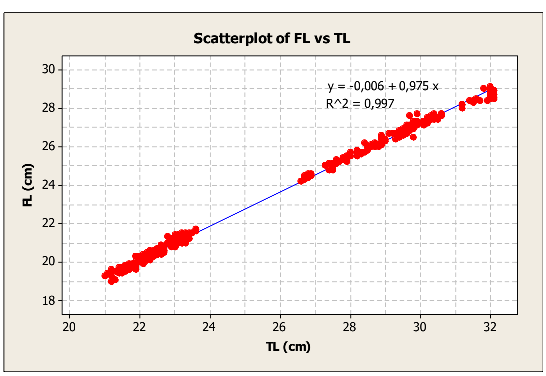
Table 3. Results of linear regression analysis for TL, FL, and SL of indian mackerel

Item	TL-FL	TL-SL	FL-SL
R	0.998	0.998	0.998
R^2	0.997	0.996	0.996
SE	0.003	0.004	0.003
A	-0.006	0.016	0.024
B	0.975	0.934	0.956
T	7.696	19.631	13.056
Model	Log FL = -0.006 + 0.975 Log TL	Log SL = 0.016 + 0.934 Log TL	Log SL = 0.024 + 0.956 Log FL

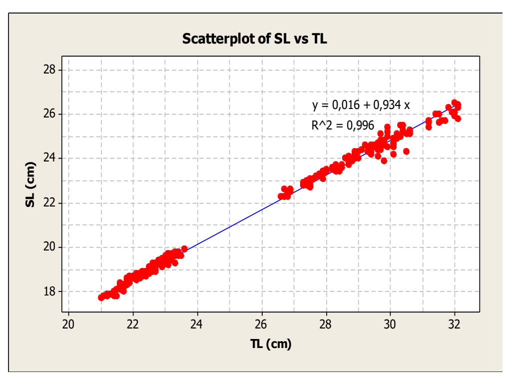
The slope values (b) in the three logarithmic forms ranged from 0.934 to 0.975, indicating a strong positive linear relationship among the length parameters. Subsequent t-tests on the slopes were performed to assess growth patterns, showing that the $t_{calculated}$ were greater than the $t_{critical}$ (α = 0.05; df = 301): 7.696 > 1.968 for TL-FL, 19.631 > 1.968 for TL-SL, and 13.056 > 1.968 for FL-SL.

These results indicate that the slopes of all logarithmic forms are statistically different from 1 (b < 1), confirming negative allometric growth, where FL and SL increase proportionally more slowly than TL. This finding reinforces the earlier interpretation of length-ratio changes across size classes, demonstrating non-proportional (allometric) growth between TL, FL, and SL in indian mackerel.

Negative allometry is common in small pelagic fish, as changes in body proportions are associated with swimming speed, movement efficiency, and schooling behavior. Indian mackerel exhibit an elongated, slender body with a deeply forked caudal fin, adaptations that facilitate fast and efficient swimming in the pelagic zone (Rahman & Hafzath, 2012). The elongated body form results in differential growth rates among specific body components (FL and SL) relative to TL, supporting the observed negative allometric pattern. Kara *et al.* (2020) reported similar findings in length-length analyses of several pelagic and demersal species in Izmir Bay, Turkey, showing that all small pelagic species exhibited negative allometry (b < 1), indicating that growth of body components was not proportional to total body length.



(a)



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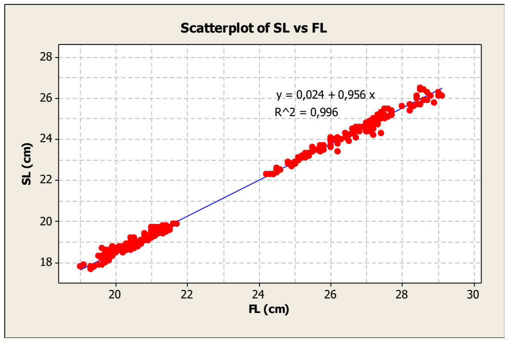

(c)

Figure 4. Scatterplots of TL, FL, and SL in indian mackerel: (a) TL-FL relationship; (b) TL-SL relationship; (c) FL-SL relationship

IV. CONCLUSIONS

Based on the morphometric analysis of indian mackerel landed in Kupang during October – November 2025, the TL ranged from 21 to 32.1 cm (mean 25.708 ± 3.601 cm), with FL ranging from 19 to 29.1 cm and SL from 17.7 to 26.5 cm. The size distribution exhibited a bimodal pattern, reflecting the population's size structure.

The FL/TL ratio decreased from 91.041% in the 21 – 21.9 cm size class to 89.701% in the 32 – 32.9 cm size class. Similarly, the SL/TL ratio declined from 84.312% to 81.617%, and the SL/FL ratio decreased from 92.614% to 90.995%, with fluctuations observed between intermediate size classes. Two-way ANOVA results indicated that both size class and ratio type significantly affected the body-length ratios ($p < 0.05$). The negative trend in ratio changes across medium to large size classes suggests that indian mackerel exhibit non-proportional (allometric) growth.

Simple linear regression analysis further confirmed negative allometric growth ($b < 1$) for all length relationships (TL-FL, TL-SL, and FL-SL). The linear relationships were very strong, with correlation coefficients of $r = 0.998$ and determination coefficients (R^2) ranging from 0.996 to 0.997. These results corroborate the length-ratio analysis, indicating that FL and SL increase proportionally more slowly than TL. This growth pattern aligns with the general characteristics of pelagic fish, which possess elongated body forms to optimize swimming efficiency and facilitate rapid movement in the water column.

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