Nekton: Jurnal Perikanan dan Ilmu Kelautan
Vol 6 Issue 2 June-November 2026, pages 103–111
ISSN 2776-2734 (online)

RESEARCH ARTICLE

Estimation of Shortfin scad (*Decapterus macrosoma*) Stock in the Waters of Nusa Laut, Maluku, Indonesia

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Abstract. The potential of marine resources from the Banda Sea, particularly the waters of Nusa Laut, represents an important economic aspect for local fishers. Several fishing fleets targeting scad, including mini purse seine vessels, are widely distributed in the area, with continuous exploitation activities occurring every week. This study aimed to analyze the growth pattern, mortality, and sex ratio of white scad (*Decapterus macrosoma*) in Nusa Laut waters, landed at Arumbai Market, Ambon. The research was conducted using a survey method from January to June 2025, with a total sample of 150 individuals. Data were analyzed based on growth pattern, fish mortality, and sex ratio analyses. The results showed that the asymptotic length ($L\infty$) was estimated at 24.7 cm total length (TL), with a growth coefficient (K) of 0.61 year^{-1} and a theoretical age at zero length (t_0) of −0.25 year. The fishing mortality (F) value was 0.46 year^{-1}, the total mortality (Z) was 1.80 year^{-1}, and the natural mortality (M) was 1.34 year^{-1}, resulting in an exploitation rate (E) of 0.25. The sex ratio analysis conducted from February to June indicated that the proportion of male and female fish was in a balanced condition, with a ratio of 1:1. Based on the exploitation analysis, the length corresponding to half of the asymptotic length ($L\infty/2$ = 12.35 cm TL) indicated that the captured fish were still relatively small. Therefore, the biological characteristics of white scad caught in Nusa Laut waters, Central Maluku, and landed at Arumbai Market, Ambon City, indicate that the fish are predominantly captured at a small size with a relatively low exploitation level.

Keywords: white scad, growth pattern, mortality, sex ratio, Nusa Laut waters.

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How to cite (APA Style):
Latuconsina, H. H. R., Soukotta, I. V. T., Fakaubun, F. R., Tino, W., Latue, M. U., Barcinta, M. F., & Moniharapon, D. (2026). Estimation of Shortfin scad (Decapterus macrosoma) Stock in the Waters of Nusa Laut, Maluku, Indonesia. *Nekton*, *6*(2), 103–111. https://doi.org/10.47767/nekton.v6i2.1099

https://ojs.poltesa.ac.id/index.php/nekton
Received: 12 Nov 2025; Revised: 15 Apr 2026; Accepted: 29 Aug 2026; Published: 03 Sep 2026

INTRODUCTION

Scad fish are among the important groups of small pelagic fish that play a significant role in capture fisheries activities and serve as an important source of food for communities in Maluku. One of the widely utilized species is the white scad (*Decapterus macrosoma*). The supply of scad fish marketed in Ambon City originates from several fishing grounds in Maluku and is distributed through various marketing chains before reaching consumers. Leiwakabessy *et al.* (2021) reported that scad fish are among the fisheries commodities with an important supply chain in Ambon City. One of the fishing areas contributing to scad catches is the Nusa Laut waters, Central Maluku, where the catches are landed and marketed through several locations, including Arumbai Market in Ambon. This condition indicates that scad resources in Nusa Laut waters possess both biological and economic values for coastal communities and fisheries stakeholders.

The availability of small pelagic fish resources is strongly influenced by marine environmental dynamics. Variations in sea surface temperature, primary productivity, chlorophyll-*a* concentration, seasonal patterns, and water mass dynamics may affect fish distribution and availability in fishing grounds. Marpaung *et al.* (2022) demonstrated that primary productivity and chlorophyll-*a* conditions in the Banda Sea exhibit spatial and temporal variations associated with oceanographic dynamics. These conditions may influence the availability of pelagic fish resources that depend on aquatic productivity as part of the food web. Hatidja *et al.* (2025) also reported a relationship between variations in oceanographic parameters and catches of scad fish (*Decapterus* spp.). Therefore, environmental changes in marine ecosystems, combined with fishing pressure, may influence population structures and scad fish catches over time.

The continuous utilization of scad fish resources needs to be accompanied by stock condition information to ensure that fishing activities do not exceed the population's capacity for regeneration. Biological information, including size distribution, growth patterns, mortality rates, exploitation levels, and sex ratios, represents essential parameters for assessing the condition of fish populations. Studies on *Decapterus macrosoma* have been conducted in several regions of Indonesia and have revealed different population conditions among locations. Astuti *et al.* (2021), for instance, reported an exploitation rate of 0.60 for scad fish in Pekalongan waters, indicating relatively high fishing pressure. Septiyaningrum *et al.* (2023) recorded a higher exploitation rate for scad fish landed at TPI Pondokdadap, East Java. In contrast, Tangke and Talib (2023) reported that the stock condition of scad fish in Ternate Island waters had not yet reached an overfished condition. These differences indicate that population characteristics and exploitation levels of scad fish are location-specific; therefore, information from one area cannot be directly generalized to describe stock conditions in another area.

Research on white scad has also been developed in the Maluku region. Pattikawa *et al.* (2017) investigated size distribution, length–weight relationships, and age groups of *D. macrosoma* in the eastern waters of Ambon Island and identified several age groups within the exploited population. Meanwhile, La Ima *et al.* (2023) examined biological aspects of scad fish in Banda waters, including length–weight relationships, sex ratios, condition factors, gonad maturity stages, gonadosomatic index, length at first maturity, and fecundity. Another study by Soukotta *et al.* (2024b) in the northern Banda Sea demonstrated that length at first capture, growth patterns, and length at first maturity are important parameters for evaluating scad fish stock conditions. Research on white scad landed in Waai Village, Central Maluku, also revealed growth characteristics that differed from those reported in other locations. These variations indicate that population characteristics of white scad may differ even within geographically adjacent areas of Maluku.

Although previous studies have provided valuable information regarding the biological characteristics and population dynamics of white scad, specific information describing white scad populations originating from Nusa Laut waters remains limited. Previous studies in Maluku have mainly focused on Ambon Island waters, Banda waters, the northern Banda Sea, and other areas in Central Maluku, with different analytical focuses. Pattikawa *et al.* (2017) emphasized size distribution and age structure, whereas La Ima *et al.* (2023) focused primarily on reproductive aspects. Soukotta *et al.* (2024b) provided information regarding stock condition, growth patterns, and length at first capture; however, the study was conducted in different waters. Therefore, the research gap does not lie in the absence of studies on *D. macrosoma* in Maluku, but rather in the limited availability of integrated information combining size distribution, growth parameters, natural mortality, fishing mortality, total mortality, exploitation rate, and sex ratio to describe the population condition of white scad specifically originating from Nusa Laut waters. Location-specific biological information is essential because differences in environmental conditions, fishing grounds, fishing gears, and exploitation intensity may produce different population parameters. Hence, research in Nusa Laut waters is required as baseline information to determine whether the exploited fish population remains within sustainable conditions or has shown indications of fishing pressure that require management attention.

Based on these considerations, this study aimed to analyze the growth pattern, mortality, exploitation rate, and sex ratio of white scad (*Decapterus macrosoma*) originating from Nusa Laut waters and landed at Arumbai Market, Ambon. The findings are expected to provide updated information regarding the biological characteristics and exploitation status of white scad resources in Nusa Laut waters. Such information can serve as baseline data for stock condition monitoring and provide scientific considerations for the sustainable utilization and management of white scad resources in Central Maluku.

METHODS

Study Area and Sampling Method

This study was conducted in the Nusa Laut waters, with samples collected from fish landed at Arumbai Market, Ambon. Sampling was carried out from January to June 2025. According to Ashwin *et al.* (2025), a survey represents a field-based data collection framework supported by questionnaires and direct observations to obtain representative sample data. The survey method is commonly applied because it is relatively simple in implementation; however, the collected data can be further analyzed using complex statistical approaches (Syahrizal & Jailani, 2023).

Primary data were obtained from direct measurements of fish specimens during the landing process. The equipment used included a digital camera, notebook and stationery, a ruler with 1 mm precision, a 5 kg capacity weighing scale, and Microsoft Excel for data tabulation. The biological material used in this study was white scad (*Decapterus macrosoma*). Fish samples were randomly selected, representing approximately 10% of the landed catch.

Data Processing and Growth Analysis

The processed standard length data of white scad were systematically tabulated using Microsoft Excel into length frequency intervals of 2.5 cm. The observed standard length range varied from 12.3 cm to 24.5 cm. Subsequently, length-frequency data and the number of individuals in each length class were analyzed using the FiSAT II software package (Gayanilo *et al.*, 2005).

Growth parameters, including asymptotic length ($L\infty$) and growth coefficient (K), were estimated using FiSAT II through the ELEFAN I routine based on length-frequency data (Gayanilo *et al.*, 2005). The ELEFAN I analysis provided estimates of $L\infty$ and K, which were subsequently used to estimate the theoretical age at zero length (t_0). The value of t_0 was obtained through logarithmic transformation, followed by calculation using the von Bertalanffy growth function according to Sparre and Venema (1998).

The von Bertalanffy growth equation was expressed as follows:

$$Lt = L\infty\ (1 - e^{-K(t-to)}) \quad (1)$$

Where:

Lt : length of fish at a certain age
L∞ : asymptotic length (cm FL, cm SL, or cm TL)
K : growth coefficient indicating slow or rapid individual growth
t : age of fish
t_0 : theoretical age when fish length is zero

According to Pauly (1983), the theoretical age at zero length (t_0) was estimated using the following equation:

$$\text{Log} -(t_0) = -0{,}3922 - 0{,}2752 \text{ Log L} -1{,}038 \text{ Log K} \tag{2}$$

The calculation was performed by inserting age values (*t*) in the left column and calculating fish length using Equation (1) in the right column. The initial age was set at zero years to represent the beginning of individual fish growth. The resulting relationship between age and length forms a curved growth trajectory known as the von Bertalanffy growth curve.

Mortality and Exploitation Analysis

The estimation of mortality parameters was used to evaluate population dynamics and exploitation status of white scad in Nusa Laut waters. Natural mortality (M) was estimated following Pauly (1983) and Sparre and Venema (1998) using the following equation:

$$\text{Log M} = -0{,}0066 - 0{,}279 \text{ Log } L\infty + 0{,}654 \text{ Log K} + 0{,}4634 \text{ Log T} \tag{3}$$

Where:
M : natural mortality without fishing pressure caused by predators or humans
L∞ : asymptotic length
K : growth coefficient (cm/year)
T : mean water temperature (°C)

Sex Ratio Analysis

The sex ratio analysis was conducted to determine the proportion between male and female individuals. The sex ratio was calculated using the following equation (Khouw, 2016):

$$NK = \frac{N_{JB}}{N} \; x \; 100 \tag{4}$$

Where:
NK : sex ratio
NJB : number of male or female
N : total number of sample observed

The equation describes whether the population is in a balanced condition or not based on the proportion of male and female individuals. The obtained Chi-square value was used to determine whether the observed sex ratio significantly differed from the expected ratio of 1:1. The equilibrium condition of the sex ratio was further tested using the Chi-square (x^2) test following Nuryadi *et al.* (2017):

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \tag{5}$$

Where:
x^2 : calculated Chi-square value
O_i : observed frequency
E_i : expected frequency

RESULTS AND DISCUSSION

Length Distribution of White Scad (*Decapterus macrosoma*)

The length distribution of white scad (*Decapterus macrosoma*) collected from the eastern waters of Nusa Laut consisted of 150 individuals, with total length (TL) ranging from 12.5 to 24.5 cm (Figure 1). The length-frequency distribution showed that individuals were predominantly distributed within the 20.0–23.0 cm TL size classes, while smaller individuals (<15 cm TL) were represented at relatively low frequencies. This pattern indicates that the catch was mainly composed of intermediate-sized individuals that had reached an advanced growth stage. The occurrence of several length groups suggests the presence of multiple cohorts within the population, reflecting continuous recruitment and variation in individual growth. Length-frequency analysis is widely applied in fisheries population studies to describe stock structure, recruitment patterns, and the response of fish populations to exploitation pressure (Froese & Pauly, 2024).

The dominance of medium-sized individuals in the catch may be associated with fishing gear selectivity and the schooling behavior of small pelagic fishes, where fishing operations tend to capture fish within specific size ranges. The absence of larger individuals (>24.5 cm TL) may indicate the combined effects of fishing mortality, natural mortality, and biological characteristics of *D. macrosoma*. Similar size structures have been reported for *Decapterus* species in Indonesian waters, where catches are generally dominated by certain length groups due to differences in recruitment, habitat distribution, and exploitation intensity (Tangke & Talib, 2023). Although the observed length distribution suggests that most individuals were within a relatively favorable size range for exploitation, continuous monitoring of length composition is necessary because a shift toward smaller size classes may indicate increasing fishing pressure and potential impacts on stock sustainability.

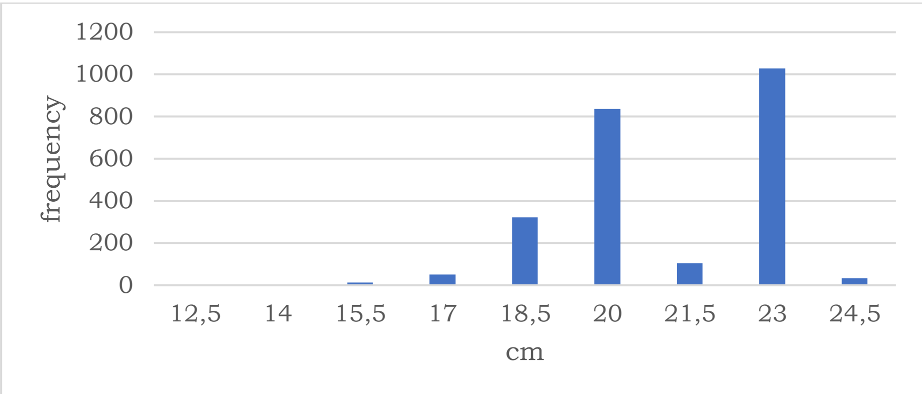

Figure 1. Total Length Distribution of White Scad (*Decapterus macrosoma*)

Growth Pattern Analysis

The growth analysis of white scad (*Decapterus macrosoma*) estimated an asymptotic length ($L\infty$) of 24.70 cm TL, with a growth coefficient (K) of 0.61 year^{-1} and a theoretical age at zero length (t_0) of −0.25 year. The estimated growth parameters obtained in this study differed from those reported by Soukotta *et al.* (2024a), who recorded an asymptotic length ($L\infty$) of 37.00 cm and a growth coefficient (K) of 1.01 year^{-1} for white scad. The differences in growth parameters may be associated with variations in environmental conditions, fishing pressure, habitat characteristics, and sampling locations. These findings indicate that population growth characteristics of white scad may vary among fishing areas within the Maluku region.

The von Bertalanffy growth model indicated that white scad exhibited relatively rapid growth during the early life stages, followed by a gradual reduction in growth rate as individuals approached the asymptotic length. This growth pattern is consistent with the biological characteristics of fish, in which growth rates generally decline as individuals become larger and allocate more energy toward reproduction and physiological maintenance (Flinn & Midway, 2021; Lee *et al.*, 2020).

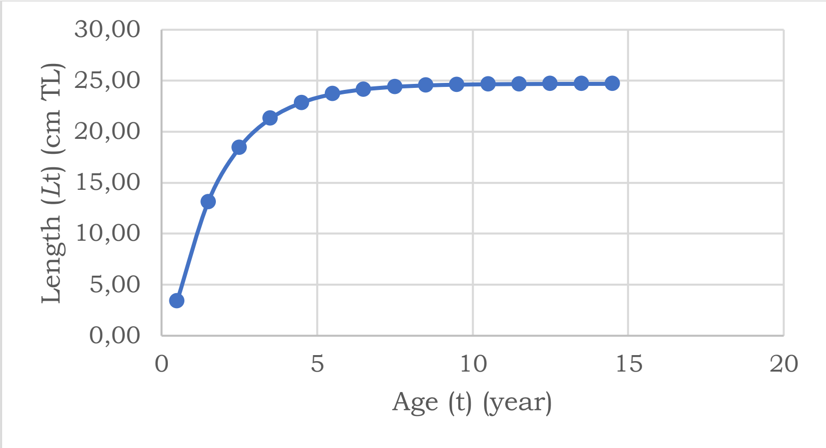

Figure 2. Estimation of von Bertalanffy Growth Pattern of White Scad in the Eastern Waters of Nusa Laut, Central Maluku

Figure 2 illustrate that white scad gradually approached the estimated asymptotic length of 24.70 cm TL according to the predicted growth trajectory. The asymptotic length ($L\infty$) represents the theoretical average maximum size that individuals in a population can achieve under specific environmental and biological conditions, rather than the actual maximum length or maximum lifespan of the species. Therefore, the von Bertalanffy growth model describes the pattern of length increment over time and the tendency of individuals to approach $L\infty$, but it should not be interpreted as an estimate of population longevity (Lee *et al.*, 2020; Flinn & Midway, 2021).

The growth parameters obtained in this study differed from those reported by Soukotta *et al.* (2024a), who estimated an asymptotic length ($L\infty$) of 37.00 cm and a growth coefficient (K) of 1.01 year^{-1} for white scad populations from different waters of Maluku. Differences in growth parameters among populations are commonly observed in fish stocks and may be associated with variations in environmental conditions, habitat characteristics, temperature, food availability, fishing intensity, recruitment dynamics, and population structure. Environmental variability, particularly temperature and ecosystem productivity, can influence life-history traits by modifying growth rates and asymptotic size among fish populations (Kjesbu *et al.*, 2020; Flinn & Midway, 2021).

Mortality and Exploitation Rate

The mortality analysis showed that fishing mortality (F) was 0.46 year^{-1}, total mortality (Z) was 1.80 year^{-1}, natural mortality (M) was 1.34 year^{-1}, and the exploitation rate (E) was 0.25 (Figure 3 and Table 1) (Sparre & Venema, 1998).

Table 1. Mortality Parameters of White Scad in Several Fishing Areas in Indonesia

Fishing Location	M	F	Z
Pekalongan Waters	1.61	2.41	4.02
East Java	1.01	4.11	5.12
Nusa Laut Waters	1.34	0.46	1.80

The exploitation rate of white scad in Nusa Laut waters remains relatively low, with values below the commonly used optimal exploitation reference level ($E < 0.5$). In comparison, white scad populations in Pekalongan and East Java showed higher exploitation rates of 0.60 and 0.80, respectively (Astuti *et al.*, 2021; Septiyaningrum *et al.*, 2023), indicating greater fishing pressure in these areas.

The mortality analysis indicated that natural mortality contributed substantially to population reduction, with an estimated value of 1.34 year^{-1}. In contrast, fishing mortality was relatively low, suggesting that current fishing activities in Nusa Laut waters have not yet exerted excessive pressure on the white scad population. Soukotta *et al.* (2024b) reported higher mortality values in Eri Village waters, with Z = 3.45, M = 1.70, F

= 1.75, and an exploitation rate of E = 0.51, indicating different population dynamics compared with the present study.

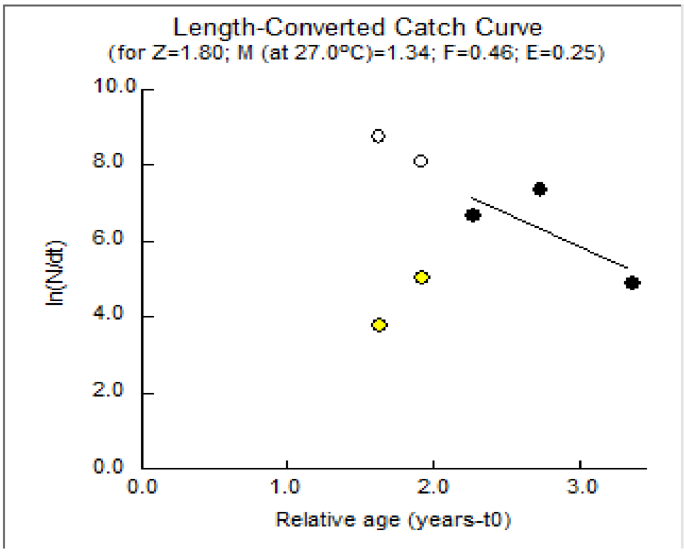

Figure 3. Mortality Curve of White Scad (*Decapterus macrosoma*)

The relationship between growth parameters (Figure 2), mortality characteristics (Figure 3), and exploitation status indicates that the captured fish were still relatively small. Based on the estimated asymptotic length, half of the asymptotic length ($L\infty/2$) was calculated as 24.7/2 = 12.35 cm TL. This value indicates that fishing activities captured individuals that had reached a relatively small size. A similar condition was reported by Soukotta *et al.* (2024b), who found that half of the asymptotic length of white scad was approximately 16.6 cm.

Sex Ratio Analysis

The sex ratio analysis of white scad during the observation period from January to July 2025 showed variations among months. The monthly distribution of male and female individuals is presented in Table 2. During the study period from January to July, a total of 1,607 white scad individuals were examined, consisting of 773 males and 834 females (Table 2). Female individuals were generally more abundant than males in most observation periods, except in January and April. However, the Chi-square test showed that the calculated x^2 values were lower than the critical x^2 value, particularly during February–June, indicating that the sex ratio between male and female individuals was statistically balanced at approximately 1:1.

Table 2. Sex Ratio of White Scad (*Decapterus macrosoma*)

Month	Male	Female	Male: Female Ratio	Description	Chi-square Calculated and Critical Value
January	8	4	2:1	Unbalanced	0.50 < 3.84
February	21	30	1:1	Balanced	1.43 < 3.84
March	150	171	1:1	Balanced	1.14 < 3.84
April	34	23	1:1	Balanced	0.68 < 3.84
May	50	54	1:1	Balanced	1.08 < 3.84
June	500	529	1:1	Balanced	1.06 < 3.84
July	10	23	1:2	Unbalanced	2.30 < 3.84
Total	773	834			

Previous studies have reported variations in sex ratios of white scad populations in different regions. La Ima *et al.* (2023) found an unbalanced sex ratio of 1:0 for white scad populations in the Banda Sea, whereas Sari *et al.* (2024) reported a balanced sex ratio of 1:1 for white scad populations in East Java waters. Differences in sex ratio among locations may be influenced by spawning migration patterns, fishing selectivity, seasonal variation, and environmental conditions affecting population structure.

CONCLUSION

The white scad (*Decapterus macrosoma*) population in Nusa Laut waters exhibited a growth pattern characterized by an asymptotic length ($L\infty$) of 24.70 cm TL, a growth coefficient (K) of 0.61 year^{-1}, and a theoretical age at zero length (t_0) of −0.25 year. The mortality analysis indicated relatively low fishing pressure, with an exploitation rate of 0.25, while the sex ratio during the observation period was generally balanced between males and females. Based on the comparison between the observed catch size and half of the asymptotic length ($L\infty/2$), most captured individuals were still relatively small, indicating the need for careful fisheries management to ensure the sustainable utilization of white scad resources in Nusa Laut waters.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to God Almighty for His blessings and grace, enabling this research to be conducted and this manuscript to be completed successfully. The authors also extend their appreciation to all parties who provided support throughout the research process, particularly the students who assisted in data collection and data processing activities. Appreciation is further expressed to those who provided guidance, technical assistance, and support during the implementation of the research and the preparation of this article.

AUTHOR CONTRIBUTIONS STATEMENT

The authors declare that the contributions of each author to this work are as follows: H.H.R.L. contributed to data collection and acquisition of time-series data. I.V.T.S. supervised the research, provided methodological guidance, and contributed to data processing and interpretation. W.T. prepared the research location map and contributed to the methodology section. M.U.L. and F.R.F. contributed to data completeness and manuscript preparation. All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest with any party regarding the publication of this article

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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