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POPULATION DYNAMICS OF KAWAKAWA (*Euthynnus affinis*) LANDED AT PPI UJONG BAROH, WEST ACEH

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ABSTRACT

This study analyzed the population dynamics of kawakawa tuna (*Euthynnus affinis*) landed at PPI Ujong Baroh, West Aceh, from May to August 2025, using length-frequency data and the Von Bertalanffy growth model. A total of 815 individuals were measured to estimate growth, mortality, and exploitation parameters. The fork length ranged from 22–69 cm, dominated by medium-sized fish (30–37 cm FL), with the length at first capture (Lc = 33 cm FL) notably smaller than the length at first maturity (Lm ≈ 42–43 cm FL). Growth analysis indicated rapid juvenile growth, characterized by an asymptotic length ($L\infty$) of 90 cm and a relatively high growth coefficient (K), while recruitment occurred periodically throughout the year. Mortality estimates showed total mortality (Z) of 4.77/year, natural mortality (M) of 1.45/year, and fishing mortality (F) of 3.32/year, resulting in an exploitation rate (E) of 0.70, which exceeds the optimal reference point (E = 0.5). These findings indicate that the kawakawa tuna stock in West Aceh is currently overexploited. This study provides the first updated, location-specific population parameter estimates for *E. affinis* in West Aceh waters, offering a critical scientific baseline for regionally adaptive fisheries management. Science-based management measures are therefore recommended, including implementing a minimum landing size of ≥43 cm FL, seasonal closures during spawning periods, effort control, and strengthened fisher participation to ensure long-term stock sustainability.

Keywords: *Euthynnus affinis*, Growth, Mortality, Exploitation Rate, West Aceh

1. INTRODUCTION

Capture fisheries play an essential role in supporting food security, improving fishermen's welfare, and sustaining regional economies in Indonesia. As a maritime nation, Indonesia is rich in high–value small pelagic fish resources such as tuna, mackerel, and sardine[1]. These species are not only the main commodities in domestic trade but also provide affordable sources of animal protein for the wider community. Among these small pelagic species, the kawakawa tuna (*Euthynnus affinis*) is one of the dominant commodities with significant economic value, both for local consumption and for processed products such as fish balls[2], nuggets, floss, and even tuna pizza[3]. Its major role makes kawakawa tuna important not only for nutritional fulfilment but also as a key pillar supporting the livelihoods and economies of coastal communities. At the regional and international levels, *E. affinis* has also been reported as a key small pelagic resource in the Indian Ocean, Arabian Sea, and several Southeast Asian waters, highlighting its broad ecological and economic importance beyond Indonesia.

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The waters of West Aceh, directly bordering the Indian Ocean, are strategically important for the development of capture fisheries. This area is characterized by the upwelling phenomenon, which affects chlorophyll-a distribution and indirectly influences fish resource availability[4]. The PPI Ujong Baroh serves as one of the main landing centres for kawakawa tuna along the west coast of Aceh. Fishing activities in this area involve numerous fishermen using various fishing gears, such as handlines, traps, longlines, and gill nets[5]. The contribution of kawakawa tuna in West Aceh is not limited to protein supply but also supports the processing, distribution, and marketing chains that provide a significant economic impact for local communities. Comparable landing sites in other parts of the Indian Ocean region have shown that local fishing practices and environmental conditions strongly influence population structure and exploitation status of *E. affinis*, suggesting the importance of site-specific assessments.

However, increasing market demand and high consumption rates have continuously driven fishing pressure on kawakawa tuna[6]. The biological characteristics of this species, fast growth and wide migratory behaviour[7] make it highly vulnerable to excessive fishing pressure. Overfishing may cause drastic and prolonged population declines, potentially leading to depletion[8]. Signs of over-exploitation can be observed through annual catch fluctuations and decreasing fish sizes[9]. This situation may lead to uncertainty in fishery sustainability if not accompanied by a comprehensive understanding of stock conditions. Similar indications of high exploitation levels have been reported in regional and international studies, where fishing mortality of *E. Affinis* often approaches or exceeds optimal reference points.

Research on the population dynamics of pelagic fish in Indonesia has generally focused on large-scale assessments using regional production data or generalized biological parameters[10,11]. However, specific studies on the population dynamics of *E. affinis* at PPI Ujong Baroh, West Aceh, remain very limited. However, local information on growth, mortality, and exploitation parameters is essential for formulating sustainable fishery management strategies suited to local ecological and socio-economic characteristics[12]. The absence of such location-specific biological parameters limits the effectiveness of fisheries management measures when applied uniformly across different regions.

Based on these considerations, research on the population dynamics of kawakawa tuna landed at PPI Ujong Baroh is urgently needed. This study aims to analysed growth parameters, mortality, and exploitation rates of kawakawa tuna as a scientific basis for developing recommendations for sustainable fishery management. By understanding the population dynamics of this species, it is expected that management policies can be formulated to ensure resource sustainability while improving the welfare of fishing communities in West Aceh.

This study offers novelty by providing empirical, site-based population dynamic data from PPI Ujong Baroh, which can be directly compared with regional and international studies and used to support locally adaptive fisheries management.

2. RESEARCH METHOD

Time and Place

This research was conducted from May to August 2025. The sampling location was Ujong Baroh Coastal Fishing Port (PPI Ujong Baroh), which serves as the landing site for fish caught in the waters of West Aceh (Figure 1). Sampling activities were conducted throughout the study period to capture temporal variation in landings, covering multiple fishing days each month during the May–August 2025 observation period.

Method

This study employed a survey method with a random sampling technique. The random sampling was carried out by collecting tuna specimens available at PPI Ujong Baroh without specific selection criteria, representing the tuna population in the area. Sampling was conducted on multiple landing days each month, with specimens taken from different fishing vessels upon landing to minimize bias associated with individual boats or fishing trips. The sampling frequency was adjusted to the landing intensity at PPI Ujong Baroh, ensuring that samples reflected the temporal variability of catches during the study period. Although samples were collected at the landing site, potential landing bias related to gear selectivity and fishing effort was accounted for by including specimens from various fishing gears operating in the area.

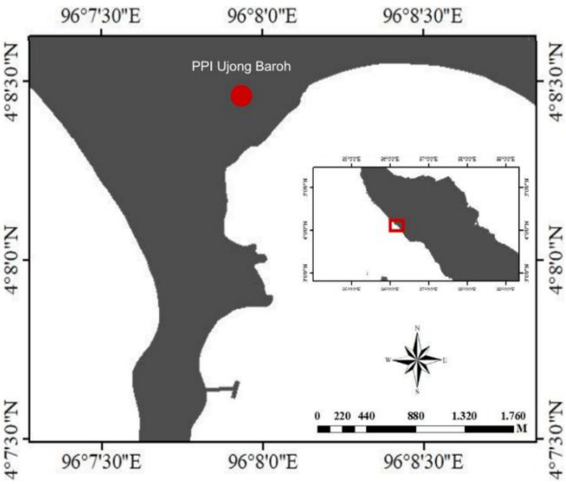

Figure 1. Location of PPI Ujong Baroh

Measured Parameters

Length Frequency Distribution

The length frequency distribution of tuna was calculated based on total length measurement data, processed using Microsoft Excel through the following steps: determining the maximum and minimum lengths, calculating the data range, the number of classes (1 + 3.32 log n), class width (range/number of classes), class interval (width + 1), and organizing the class intervals along with their frequencies.

Growth Parameters

The growth parameters analyzed included the asymptotic length ($L\infty$), growth coefficient (K), and theoretical age at zero length (t_0)[13]. These parameters were estimated using the Von Bertalanffy growth model[14]. The values of $L\infty$ and K were obtained using the ELEFAN I method available in the FISAT II software, while the estimation of t_0 was calculated using the empirical formula proposed by Pauly[11].

$Lt = L\infty\,(1 - \exp -K\,(t - t0))$

$\text{Log}\,(-t0) = -0{,}3922 - 0{,}2752 \log L\infty - 1{,}038 \,\text{Log}\, K$

Mortality and Exploitation Rate

Total mortality (Z) was analyzed using the length-converted catch curve method by incorporating growth parameters ($L\infty$ and K)[11]. Natural mortality (M) was estimated using[15] Pauly's empirical formula.

$\text{Log}\, M = (-0{,}152) - 0{,}279\, \text{Log}\, L\infty + 0{,}6543\, \text{Log}\, K + 0{,}4634\, (\text{Log}\, T)$

Note:

M	:	natural mortality rate,
$L\infty$	:	asymptotic length in the Von Bertalanffy growth model (mm),
K	:	growth coefficient, and
T	:	Average water temperature (°C).

Fishing mortality rate (F): $F = Z - M$

The exploitation rate is determined by the ratio between fishing mortality (F) and total mortality (Z). The exploitation level (E) can be estimated using the following formula:

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

Note:
E > 0.5 = High exploitation
E < 0.5 = Low exploitation
E = 0.5 = Optimal exploitation

Data Analysis

The collected data, including size distribution, mortality rate, growth rate, and length–weight relationship, were analyzed using the FISAT II software. The results were then tabulated in tables and figures and discussed descriptively. Data analysis focused on capturing population-level patterns by integrating samples collected across different months and fishing gears, thereby reducing temporal and operational bias in parameter estimation.

3. RESULT AND DISCUSSION

Length Distribution of *E. affinis*

Sampling of *E. affinis* was conducted over a period of four months, with a total of 815 specimens collected. The length frequency of the fish was grouped into 10 classes with a 3 cm interval, showing varying frequencies across classes. The fish lengths ranged from 22 to 69 cm, with different frequencies in each length class. The highest frequency was found in the 34–37 cm class with 271 individuals, followed by the 30–33 cm class with 177 individuals, and the 26–29 cm class with 148 individuals. Meanwhile, the lowest frequencies were observed in the 22–25 cm and 66–69 cm classes, each represented by only one individual. Arnenda et al.[16] reported that in the waters of Kedonganan, Bali, *E. affinis* caught ranged from 26 to 65 cm, with an average length of 44.69 cm. Similarly, at Sungai Rengas Fishing Port, Kubu Raya Regency, the recorded minimum length was 30.7 cm and the maximum length was 56.5 cm[17].

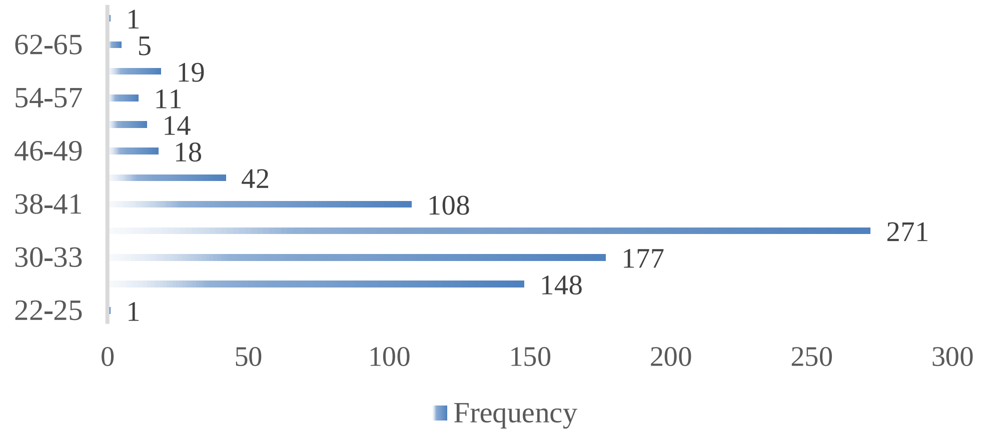

Figure 2. Frequency and length distribution of *E. affinis*

Length Frequency Distribution of *E. affinis*

The length frequency distribution of *E. affinis* showed that most of the catch was dominated by medium-sized individuals, particularly within the 30–37 cm FL range. Further analysis indicated that the length at first capture (Lc) was around 33 cm FL, representing the size at which approximately 50% of the population is caught by the fishing gear used. When compared to the length at first maturity (Lm), a notable difference was observed. According to FishBase, the global Lm of *E. affinis* ranges around 42.3 cm FL, while the Indian Ocean Tuna Commission (IOTC) sets a benchmark of 38 cm FL for the Indian Ocean region[18]. A local study in Kedonganan, Bali, reported that male fish reach gonadal maturity at approximately 45.53 cm FL.

This suggests that most of the fish caught in the study area are still in the active growth phase and have not yet reached full maturity. Such a condition indicates fishing pressure on smaller-sized fish, potentially reducing the reproductive capacity of the population since many individuals are caught before contributing to the natural stock. The dominance of smaller fish may also result from the use of non-selective fishing gear, such as nets with small mesh sizes, or fishing activities occurring along juvenile migration routes[19]. This pattern of size distribution is common in heavily exploited fisheries[20], where larger fish are caught first, leaving smaller individuals to dominate the catch.

From a long-term perspective, continuous harvesting of individuals smaller than the length at first maturity (Lc < Lm) may significantly reduce spawning stock biomass (SSB), which is a key determinant of recruitment success. A persistent decline in SSB can lead to reduced egg production and weaker recruitment pulses, ultimately threatening stock resilience even for fast-growing species such as *E. affinis*.

To ensure stock sustainability, more selective management measures are necessary. Increasing mesh size or regulating fishing seasons[21,22] could provide smaller fish the opportunity to grow to reproductive size. Additionally, setting a minimum catch size of ≥ 42 cm FL may serve as a conservative guideline, allowing most fish to reach gonadal maturity before capture. Such strategies are expected to maintain population balance and support the long-term sustainability of *E. affinis* fisheries in the region.

Growth Rate of Kawakawa (*E.affinis*)

The growth rate of *E. affinis* in 2025, based on the Von Bertalanffy growth model, is shown in Figure 2.

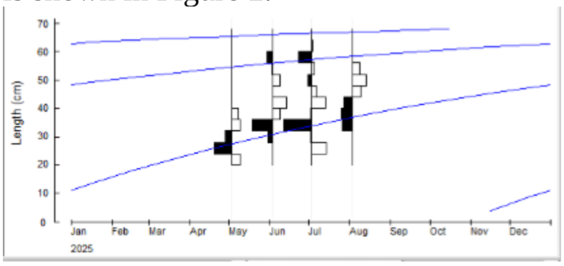

Figure 3. Growth of *E. affinis* based on the Von Bertalanffy model

This model illustrates the relationship between fish length and growth over time, where the rate of length increase is high during early life stages and gradually slows as the fish approaches its theoretical maximum, or asymptotic, length (L∞).

Based on Figure 3, the length growth of *E. affinis*) shows a rapid increase from April to August 2025. At the beginning of the year, the average individual length ranged between 20–30 cm, then increased to 40–55 cm by mid-year. The blue curve represents the Von Bertalanffy growth model, with an asymptotic length (L∞) ranging from 55.1 to 94 cm. This range indicates that, theoretically, *E. affinis* in the study waters has the potential to grow up to a maximum size of about 90 cm, provided that environmental conditions are favourable and fishing pressure remains low[18]. The maximum length of *E. affinis* in the Herlang Bay waters, Bone Gulf, can even reach 100 cm[22].

The growth coefficient (K) of *E. affinis* ranged from 0.01 to 10 per year, reflecting variation among cohorts, where rapid growth occurs during early life stages and slows as the fish approaches its maximum size. The pattern observed in the graph indicates multiple cohorts with periodic recruitment throughout the year, a common characteristic among fast-growing pelagic fish. The accelerated growth observed between April and August is likely influenced by stable water temperatures (29–31°C) and abundant food availability, while the slowdown later in the year results from energy being redirected toward reproduction. Most individuals reach the minimum catchable size (43 cm) by mid-year; therefore, the optimal fishing period is after June to avoid the capture of juveniles[23] and to maintain stock sustainability.

While rapid growth and multiple recruitment pulses may enhance short-term stock productivity, sustained high fishing pressure on juvenile and sub-adult cohorts may reduce the number of individuals surviving to spawning age, thereby weakening future recruitment despite favourable growth conditions[24].

Length-Converted Catch Curve

The age structure analysis of *E. affinis* was carried out using a length-converted catch curve to illustrate the relationship between relative age and the number of fish caught, as well as to estimate mortality and identify the fully exploited age groups. The curve shows a decline in the number of individuals with increasing relative age: the initial section is dominated by younger age groups with high abundance, while the right side forms a descending linear trend, indicating high mortality among older age groups due to fishing pressure. The sharp decline in older age classes suggests that few individuals survive to advanced ages, resulting in limited recruitment.

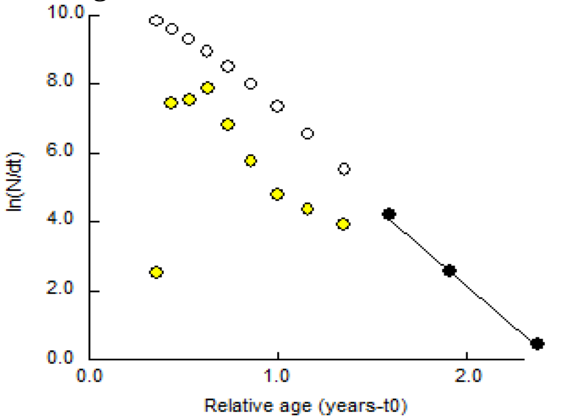

Figure 3. Length-converted catch curve of *E. affinis*

Most of the catch consisted of young to middle-aged individuals, even though *E. affinis* typically reaches first gonadal maturity at a length of approximately 43 cm. This indicates that undersized fish are being caught, potentially leading to growth overfishing or recruitment overfishing. Therefore, a minimum size limit of 43 cm should be established as a reference for gear selectivity through adjustments to mesh size or gear modification[25]. This measure should be accompanied by controlling fishing intensity and implementing seasonal monitoring during spawning periods to maintain a balanced age structure, allow fish to reproduce, and ensure the sustainability of *E. affinis* stocks[15,16].

A truncated age structure dominated by younger cohorts reduces the stability of spawning stock biomass and increases the risk of recruitment failure during years with unfavourable environmental conditions. In the long term, such population structures are less resilient to environmental variability and fishing pressure.

Mortality and Exploitation of *E. affinis*

The analysis of mortality parameters and exploitation rate provides important insights into the utilization level of *E.affinis* landed at Ujong Baroh Coastal Fishing Port (PPI Ujong Baroh). Total mortality (Z) represents the overall mortality rate within the population, consisting of natural mortality (M), which results from environmental and biological factors, and fishing mortality (F), which is caused by fishing activities. The comparison between these two components of mortality serves as a key indicator in determining the exploitation rate (E).

Table 1. Mortality parameters and exploitation rate of *E. affinis* landed at PPI Ujong Baroh

Population Parameter	Value (per year)
Total Mortality (Z)	4.77
Natural Mortality (M)	1.45
Fishing Mortality (F)	3.32
Exploitation Rate (E)	0.70

The analysis of growth parameters showed that the growth coefficient (K) of *E. affinis* was relatively high, indicating a rapid growth rate during the early life stages. The growth pattern also revealed the presence of multiple cohorts, suggesting continuous recruitment throughout the year. Growth tended to be optimal from April to August, coinciding with favourable water temperatures and abundant food availability, but began to slow down as energy was allocated toward gonadal maturation[26]. This condition implies that fishing should ideally be conducted after June, when most fish have reached the minimum catchable size (>43 cm), to avoid the dominance of juvenile fish in the catch[27].

The age structure analysis based on the length-converted catch curve showed a dominance of young to middle-aged individuals in the catch, while older age groups were relatively scarce due to high mortality rates. Total mortality (Z) indicated a sharp population decline among older groups. Furthermore, fishing mortality (F) was found to be higher than natural mortality (M), confirming that fishing activities are the main factor contributing to stock depletion.

The level of resource utilization was represented by the exploitation rate (E). According to Gulland's criteria[28], the optimal exploitation value is 0.5, meaning that 50% of the stock can be harvested sustainably. However, this study found an E value of 0.70, indicating an overexploited condition. This finding aligns with those reported by Pulungan et al.[29] in the northern Java Sea (E = 0.71) and Yudha et al.[30] in Semangka Bay (E = 0.84). The overexploited condition in West Aceh reinforces evidence that *E. affinis* stocks in Indonesian waters are generally under excessive fishing pressure.

Therefore, stricter management strategies are urgently needed, including limiting the number of fishing vessels and gear, implementing a minimum legal catch size (≥43 cm), and establishing closed seasons during spawning periods[31,32]. In addition to technical regulations, enhancing fishers' awareness through participatory approaches is crucial for ensuring the long-term sustainability of Kawakawa stocks.

Given the migratory nature of *E. affinis*, which undertakes seasonal and regional movements across fishing grounds, overexploitation in one area may have cascading impacts on stock availability and recruitment in adjacent regions. Localized intensive fishing pressure may therefore reduce the overall spawning biomass contributing to the wider population in the Indian Ocean.

These findings highlight the need for coordinated, regionally integrated fisheries management, particularly for migratory small pelagic species, combining site-based measures at PPI Ujong Baroh with broader inter-regional management frameworks to safeguard long-term stock sustainability.

4. CONCLUSION

The study indicated that the *E. affinis* stock in the waters of West Aceh was dominated by medium-sized individuals (30–37 cm FL), with the length at first capture (Lc) around 33 cm FL, smaller than the length at first gonadal maturity (Lm ±42–43 cm FL). This suggests that many individuals are caught before they have the chance to reproduce.

The fish exhibited rapid growth during the juvenile phase, with an asymptotic length ($L\infty$) of up to 90 cm and a relatively high growth rate (K), although growth slowed as they approached the maximum size. The age structure of the catch showed a dominance of young to mid-aged individuals, while older age groups were rarely found due to high fishing mortality.

Mortality analysis revealed that fishing mortality (F = 3.32/year) was higher than natural mortality (M = 1.45/year), resulting in an exploitation rate (E = 0.70) that exceeds the optimal limit (0.5). This indicates that the Kawakawa stock in West Aceh has been overexploited.

Scientifically, this study provides novel, site-specific population-dynamics parameters for *E. affinis* based on empirical landing data, providing robust local evidence that complements regional assessments and enhances understanding of stock status at the fishing-ground scale.

Therefore, science-based management measures are necessary, including establishing a minimum catch size of ≥43 cm FL, regulating fishing seasons, limiting fishing effort, and involving local fishers participatively in fisheries management to ensure the sustainability of Kawakawa stocks in the region.

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