Biological Characteristics and Spawning Potential of Neritic Tunas (*Euthynnus affinis* and *Thunnus tonggol*) in the West Coast of Peninsular Malaysia

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ABSTRACT

This study examines the biological characteristics *Euthynnus affinis* (Kawakawa) and *Thunnus tonggol* (Longtail tuna) from the West Coast of Peninsular Malaysia, focusing on length-weight relationships, length frequency distribution (LFD), condition factors, and spawning potential. Length-weight relationships showed strong allometric growth: $W = 0.00002L^{2.98}$ ($R^2 = 0.985$) for Kawakawa and $W = 0.00004L^{2.87}$ ($R^2 = 0.969$) for Longtail tuna. LFD analysis indicated gear-specific selectivity. Trawl-caught individuals were generally larger and more uniform in size compared to purse seine. Kawakawa ranged from 109–614 mm, with purse seine catches dominated by smaller sizes (mode: 205 mm) and trawl catches showing a mode of 290 mm. Longtail tuna ranged from 131–572 mm, with larger modes in trawl (405 mm) compared to purse seine (355 mm). Condition factor (K) trends showed that Longtail tuna were consistently in better condition than Kawakawa. A declining K was observed from 2022 to 2024, particularly in purse seine catches, possibly due to spawning activity, environmental changes, or fishing pressure. Length-Based Spawning Potential Ratio (LBSPR) analysis suggests both species are under growth overfishing. Kawakawa SPR declined from 0.23 (F/M = 2.46) in 2022 to 0.20 (F/M = 1.54) in 2024. Longtail tuna showed a sharper SPR drop from 0.37 to 0.14, with F/M peaking at 6.49 in 2023. In summary, Longtail tuna showed better overall condition, but both species exhibited declining reproductive potential. These findings highlight the importance of gear-based monitoring and targeted management to ensure sustainable exploitation of neritic tuna along the West Coast of Peninsular Malaysia.

Keywords : Neritic tuna, length weight relationship, spawning potential

INTRODUCTION

Unique geography, connected to larger Eurasian continent, long coastlines and large Maritime Exclusive Economic Zones (Ngeow, 2020) made Malaysia as a maritime nation surrounded by four seas, namely the Malacca Strait, South China Sea, the Andaman Sea and the Sulu Sea. Malaysia fishing area can be separated into numerous locations, including the West Coast (Malacca Strait) and East Coast (South China Sea) Peninsular Malaysia. Sabah and Sarawak fishing area including the Sulu and Celebes Sea on east coast of Sabah. Malacca Strait is part of the area included in the Indian Ocean Tuna Commission (IOTC), which includes the states of Perlis, Kedah, Penang, Perak and Selangor. On the other hand, Kelantan, Terengganu, Johor, Sabah and Sarawak are included in the Western and Central Pacific Fisheries Commission (WCPFC) from the convention of Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean. The vastness of the Exclusive Economic Zone in Malaysia is 334,671 km^2 with 200 nautical miles from its shores. The EEZ of Peninsular Malaysia is bordered by Indonesia (west) and Thailand (north, Andaman Sea) while the East of Malaysia is bordered by Brunei and Indonesia on the island of Borneo (Faizal et al., 2019).

Longtail tuna (*Thunnus tonggol*), kawakawa or eastern little tuna (*Euthynnus affinis*) and frigate tuna (*Auxis thazard*) are the 3 main species that are mostly caught in Malaysian waters (Sallehudin et al., 2013). Based on Figure 1, the landing data for neritic tuna for 15 years from 2008 – 2024 showed some fairly significant trend changes. Landings for neritic tuna from 2010 to 2015 were observed to increase evenly, but there was a sharp increase in 2015 to 2017 where the highest landings were in the year 2017 (74489.09 mt). In the following year

(2018), the landing of neritic tuna plummeted to 56735.83 mt and managed to rise again in 2019 (71297.54 mt). After 2019, the trend of neritic tuna landings decreased and continues to plummet until now. Among these three species, long tail tuna is the most dominant species caught, followed by kawakawa and frigate tuna. Major contribution in neritic tuna landings are from East Coast Peninsular Malaysia.

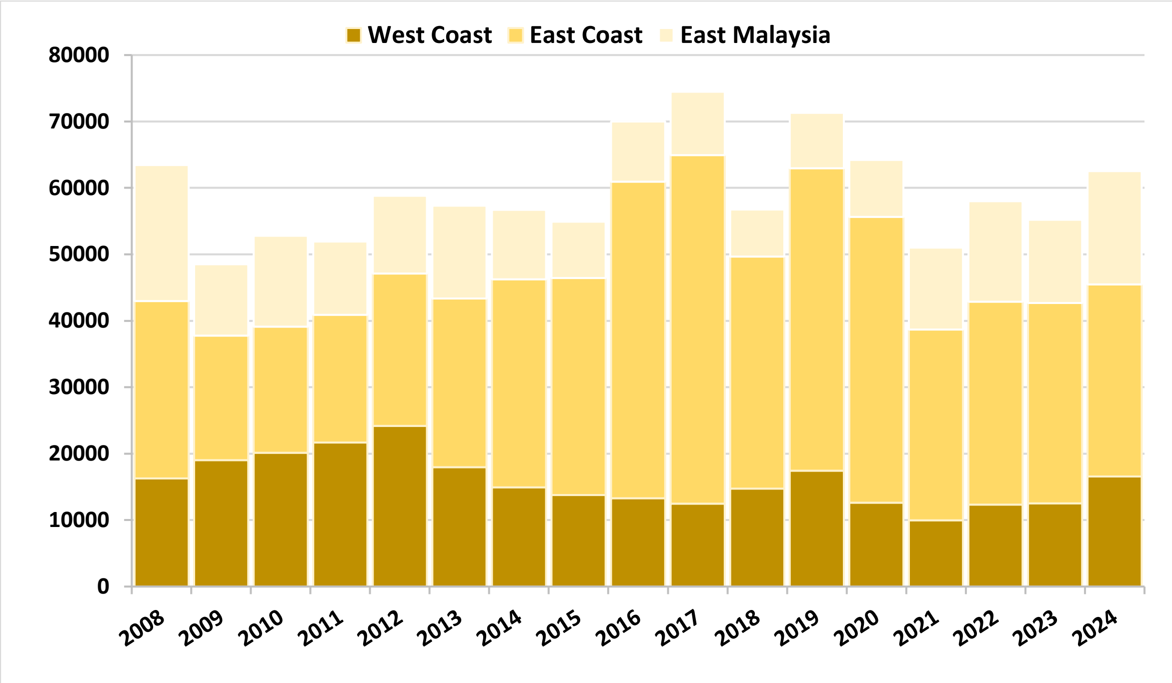

Figure 1: Neritic tuna landings 2008-2022.

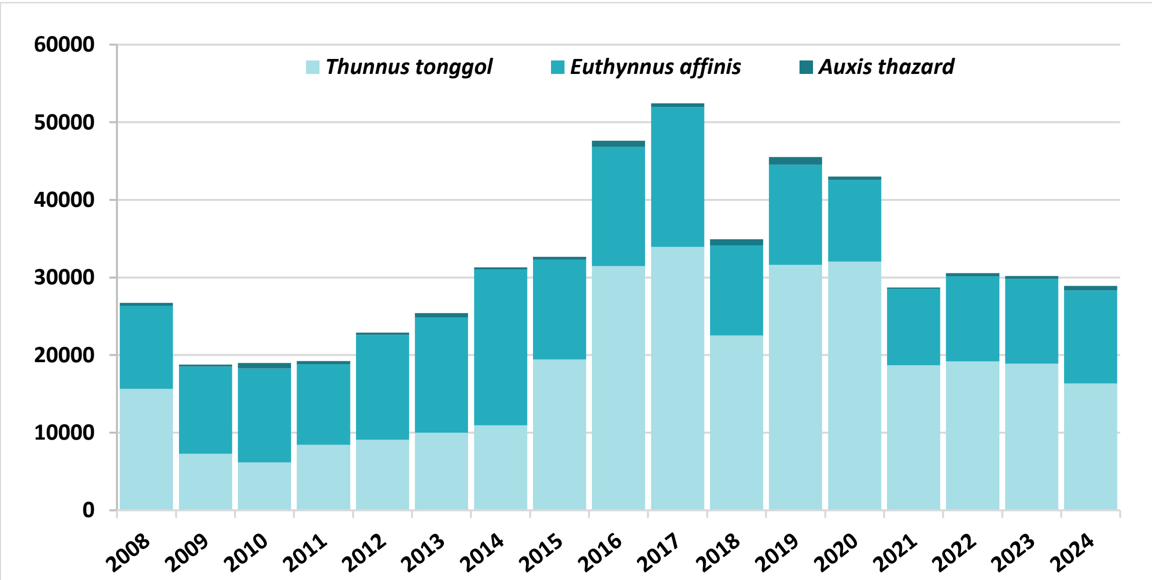

Figure 2: Landing of neritic tuna species in Malaysia.

The length-weight relationship (LWR) is a vital tool in fish biology, physiology, ecology, and fisheries assessments (Effarina et al. 2024). Initially, it was used to evaluate fish condition and identify whether somatic growth follows an isometric or allometric pattern (Ricker 1975; Oscoz et al. 2005). Additionally, LWR enables the estimation of average fish weight from known lengths, which is essential for calculating population biomass (Froese 2006). However, the precision of LWR can be affected by several factors, including seasonal variation, sex, length range, sample size, stomach content, and the statistical methods used for curve fitting (Froese 2006; Cort et al. 2015). As a result, differences in the *b* values may arise due to the influence of one or more of these factors (Zhu et al. 2009; Cort et al. 2015).

Another valuable biometric indicator is the relative condition factor (Kn), which is derived from the length-weight relationship using the formula proposed by Le Cren (1951). Kn evaluates how much an individual fish's weight deviates from the expected average weight within a sample, helping to assess the suitability of environmental conditions, such as water quality, for fish growth (Yilmaz et al., 2012; Mensah, 2015). A Kn value equal to or near 1 generally indicates good overall health or condition in fish. As stated by Le Cren (1951), deviations from a Kn value of 1 can reflect variations in food availability and the effects of physicochemical factors on fish life cycles. Moreover, when fish have access to sufficient food and favorable growth conditions, Kn values typically exceed 1, indicating optimal growth (Jisr et al., 2018).

METHODOLOGY

2.1 Study Area and Sampling

Biological data of *Euthynnus affinis* (KAW) and *Thunnus tonggol* (LOT) were collected from commercial landings along the West Coast of Peninsular Malaysia between 2022 and 2024. Samples were obtained from two major gear types: purse seine and trawl, which represent pelagic and demersal fishing strategies, respectively. For each specimen, fork length (mm) and body weight (g) were measured, and associated metadata such as gear type, date, and landing location were recorded.

2.2 Length-Weight Relationship

The length-weight relationship (LWR) was derived using the allometric equation:

$$W=aL^b$$

where *W* is body weight (g), *L* is fork length (mm), *a* is the intercept, and *b* is the slope indicating growth type (Ricker, 1975). Logarithmic transformation ($\log_{10}W = \log_{10}a + b \log_{10}L$) was applied, and parameters were estimated using linear regression. The coefficient of determination (R^2) was used to evaluate the goodness of fit. A *b* value ≈ 3 indicates isometric growth, while deviations from 3 indicate allometric growth (Froese, 2006).

2.3 Length Frequency Distribution

Length frequency data were grouped into 10 mm class intervals to examine population structure. Descriptive statistics (minimum, maximum, mean, median, mode, and standard deviation) were calculated for each gear type and species. Frequency histograms were generated to compare size distributions between gear types and identify modal classes, which may reflect recruitment pulses or gear selectivity (King, 2007).

2.4 Fulton's Condition Factor

Fulton's Condition Factor (*K*) was calculated using the formula:

$$K=W/L^3 \times 100{,}000$$

to assess the general health and nutritional status of the fish (Fulton, 1904; Le Cren, 1951). Higher *K* values indicate better condition, potentially linked to feeding success, reproductive phase, or environmental conditions. *K* was calculated by species, year, and gear type. Annual and gear-related trends were interpreted based on biological and fishery contexts.

2.5 Length-Based Spawning Potential Ratio (LBSPR)

The Length-Based Spawning Potential Ratio (SPR) was estimated using the LBSPR package in R (Hordyk et al., 2015a). This method uses length-frequency data along with life history parameters to estimate fishing mortality (F), the spawning potential ratio (SPR), and the selectivity ogive (SL_{50}, SL_{95}). Required inputs included von Bertalanffy Growth Function (VBGF) parameters (L_∞, *K*), and maturity parameters (L_{50}, L_{95}), specific to each species and region. LBSPR is particularly suitable for data-limited fisheries and provides a precautionary framework to evaluate stock status based on reproductive potential (Hordyk et al., 2015b; Prince et al., 2015). An SPR < 0.20 is considered indicative of overfishing, while higher values suggest healthier reproductive potential.

RESULTS AND DISCUSSION

3.1 Length-Weight Relationship

The length-weight relationships of *Euthynnus affinis* (kawakawa) and *Thunnus tonggol* (longtail tuna) conformed to the power function W=aLbW = aL^bW=aLb, which is typical in fish growth studies. Kawakawa demonstrated near-isometric growth, with the equation:

$$W=0.00002L^{2.98} \quad (R^2=0.985)$$

Meanwhile, longtail tuna exhibited slightly negative allometric growth, represented by:

$$W=0.00004L^{2.87} \quad (R^2=0.969)$$

The high coefficients of determination (R^2) in both species indicate a strong correlation between length and weight, suggesting consistent growth patterns across different individuals and sampling years.

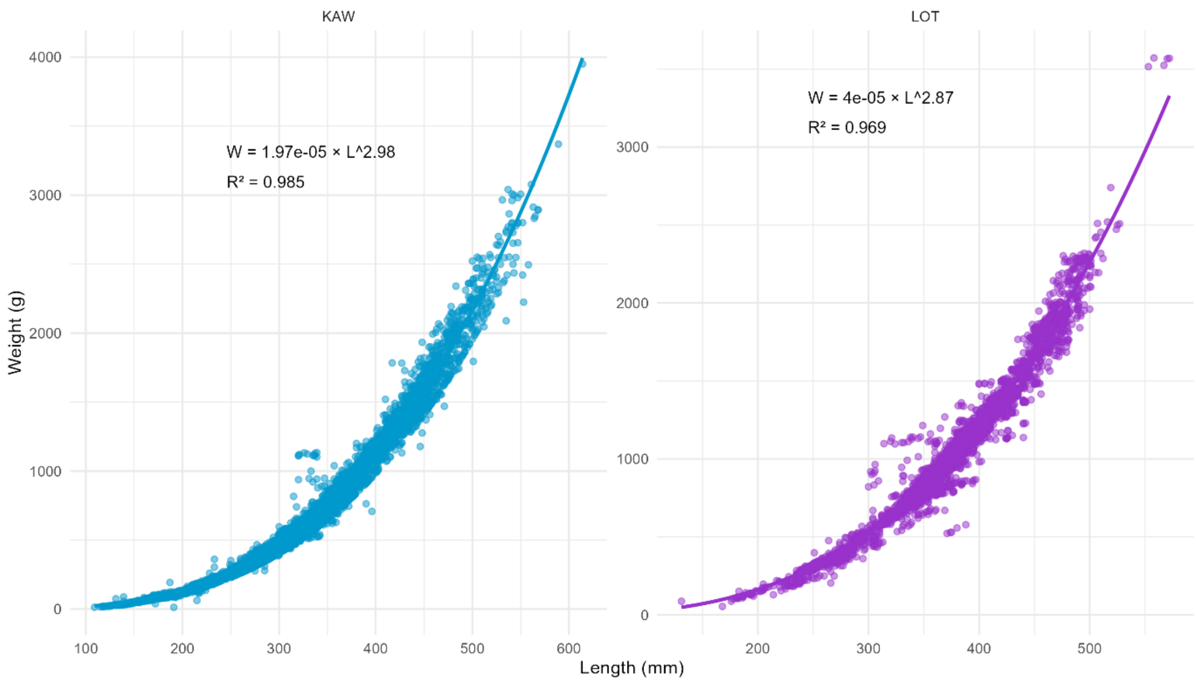

Figure 1 : Length-weight relationships of KAW and LOT from West Coast of Peninsular Malaysia

The analysis of length-weight relationships (LWR) provides valuable insight into the somatic growth patterns, condition, and reproductive status of fish species. In this study, the *b* values for *E. affinis* (2.98) and *T. tonggol* (2.87) indicate near-isometric and slightly negative allometric growth, respectively. According to Froese (2006), a *b* value close to 3 suggests isometric growth, where fish increase proportionally in length and weight. A *b* value below 3, as observed in *T. tonggol*, reflects negative allometric growth, where fish gain length faster than weight.

These findings are consistent with several studies conducted in nearby regions. For instance, *E. affinis* from the west coast of Sumatera also showed isometric growth with a *b* value of 3.06 (Noegroho et al., 2013).

On the other hand, negative allometric growth patterns have been reported for the same species in the Java Sea (Masuswo & Widodo, 2016), Maharashtra, India (Khan, 2004; Mudumala et al., 2016), and in the Persian Gulf and Oman waters (Kaymaram & Darvishi, 2012). Interestingly, positive allometric growth has also been observed in *E. affinis* from Tanzanian waters (Johnson & Tamatamah, 2013), suggesting regional variability in growth patterns.

Such variation in LWR parameters can be influenced by multiple factors, including feeding intensity, availability of food, environmental conditions, sexual maturity, and seasonal reproductive cycles (Al-Rasady et al., 2012; Ghosh et al., 2010). The present study's consistent LWR results across gear types and years suggest stable growth patterns but may still reflect gear selectivity, habitat, and timing of sampling (e.g., pre- or post-spawning).

In summary, the near-isometric growth of *E. affinis* and slightly negative allometric growth of *T. tonggol* reflect differences in species physiology and possibly ecological behavior. Continued monitoring of LWR over time can help detect environmental shifts or anthropogenic stressors affecting neritic tuna populations in Malaysian waters.

3.2 Length Frequency Distribution

Length and weight data revealed clear differences between gear types and species. Kawakawa from purse seines ranged from 109 to 589 mm, with a mean of 319.4 mm. Trawl-caught kawakawa were slightly larger on average (mean = 327.8 mm), but with less variability (SD = 69.6 mm vs. 102.4 mm in purse seine). In contrast, longtail tuna from purse seines had a wider size range (131–527 mm; mean = 366.3 mm), whereas trawl-caught individuals were generally larger and more uniform (mean = 393.3 mm, SD = 53.7 mm). This suggests that trawl gear may selectively catch larger and more mature fish due to their slower swimming behavior or demersal habits, while purse seines capture more variable size groups, including juveniles and active spawners.

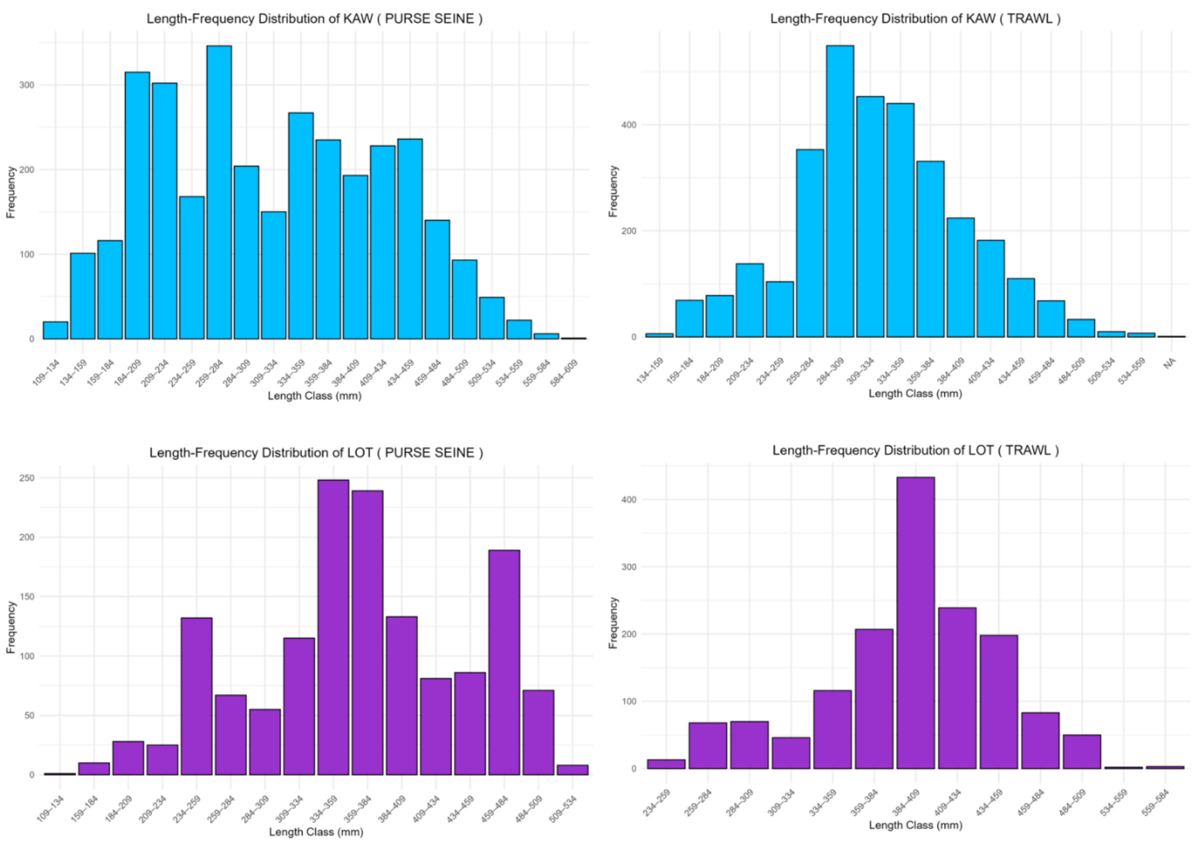

Figure 2 : Length frequency distribution of KAW and LOT

3.3 Condition Factor (K)

Condition factor (K) was used to assess the well-being of both species across gear types and years. Boxplot visualizations revealed observable differences in Fulton's K between gear types for both species (Figure 3). Longtail tuna consistently showed higher K values (range: 1.77–1.92) compared to kawakawa (range: 1.56–1.80), suggesting better body condition, possibly due to species-specific feeding strategies or metabolic efficiency. K values for both species declined slightly from 2022 to 2024, particularly in purse seine catches. This decline may reflect energy depletion during spawning, environmental stress, or overfishing impacts. Interestingly, trawl-caught longtail tuna showed a rebound in K in 2024, possibly due to the gear selecting for heavier, non-spawning individuals.

To quantitatively assess the effects of species, gear type, and their interaction on the condition factor, a two-way analysis of variance (ANOVA) was performed using aggregated yearly data. The results indicated that:

a) Species had a significant effect on Fulton's K ($F = 14.94$, $p = 0.0048$). LOT individuals exhibited significantly higher condition factors compared to KAW across all years and gear types.
b) Gear type did not significantly affect K ($F = 1.11$, $p = 0.3226$), suggesting that both purse seine and trawl gears yield fish with comparable physiological condition.

The significant difference in K between KAW and LOT, despite being caught from the same fishing grounds, likely reflects species-specific differences in body morphology, reproductive investment, and energy allocation. LOT may possess a more robust body profile or experience differing seasonal nutritional conditions that support higher energy reserves, resulting in elevated K values. On the other hand, the lack of significant gear effect implies that fishing method alone does not introduce bias in the physical condition of the catch. This consistency is important for standardizing biological assessments across gear types.

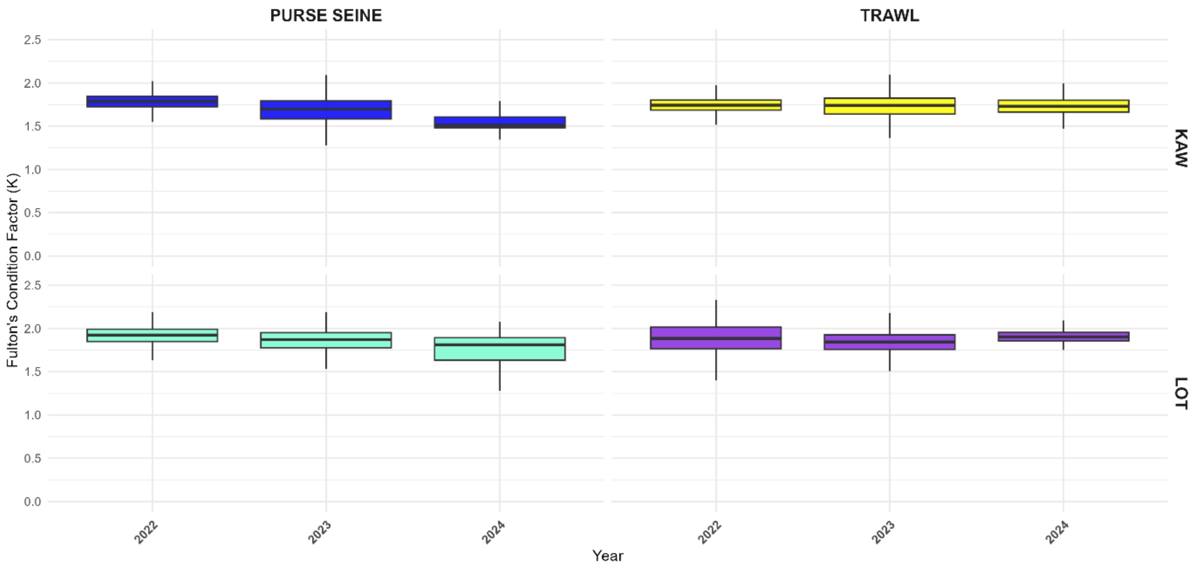

Figure 3 : Boxplot showing the distribution of condition factor (K) values for KAW and LOT sampled from the west coast of Peninsular Malaysia.

3.4 Spawning Potential Ratio (SPR)

LBSPR analysis indicated reduced spawning biomass for both species over time. For kawakawa, SPR values declined from 23% in 2022 to 20% in 2024, with a concurrent decrease in SL50 and F/M ratios, suggesting ongoing fishing pressure. Longtail tuna showed a more dramatic trend: SPR dropped from 37% (2022) to a critical low of 14% in 2024, with SL50 shifting to larger sizes, indicating a delayed maturation possibly driven by selective harvest of younger individuals. The elevated F/M values in 2023 and 2024 (6.49 and 4.78) further emphasize excessive fishing mortality.

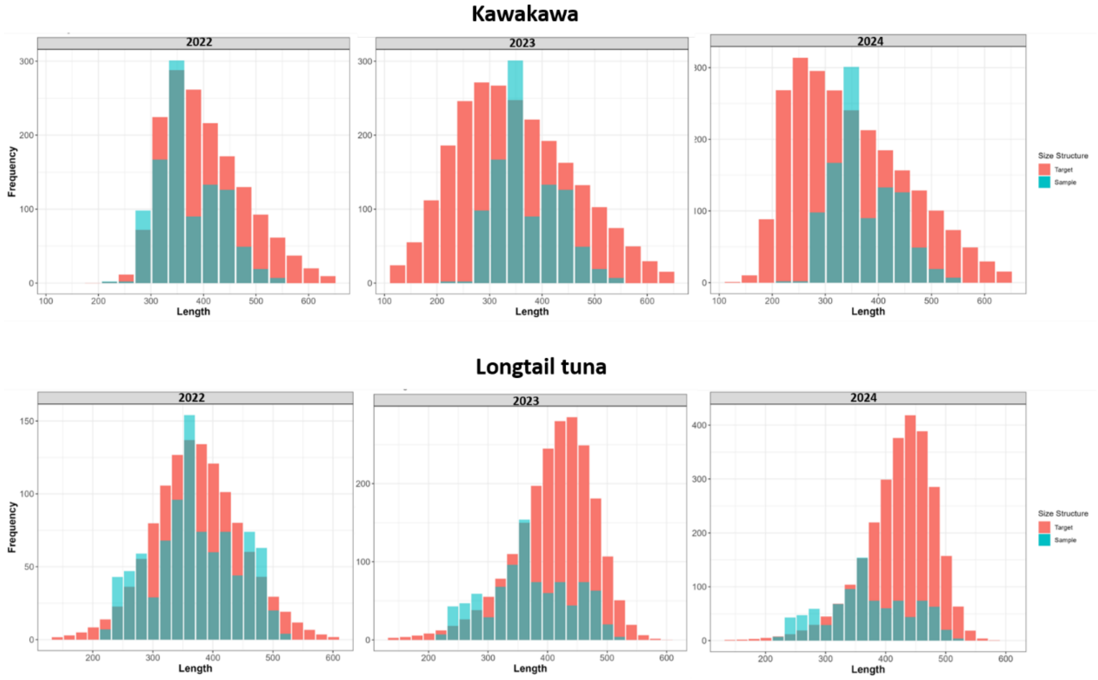

Figure 4 : Observed and theoretical size distribution of KAW and LOT under 40% SPR scenario

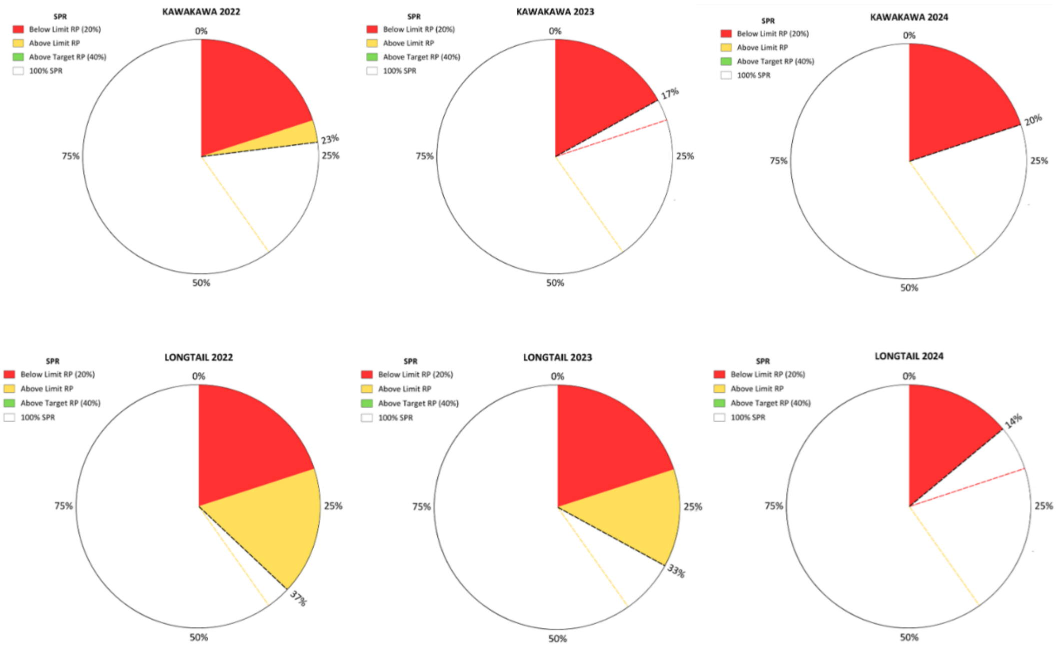

Figure 5 : Proportions of current spawning potential ratio (SPR) for KAW and LOT

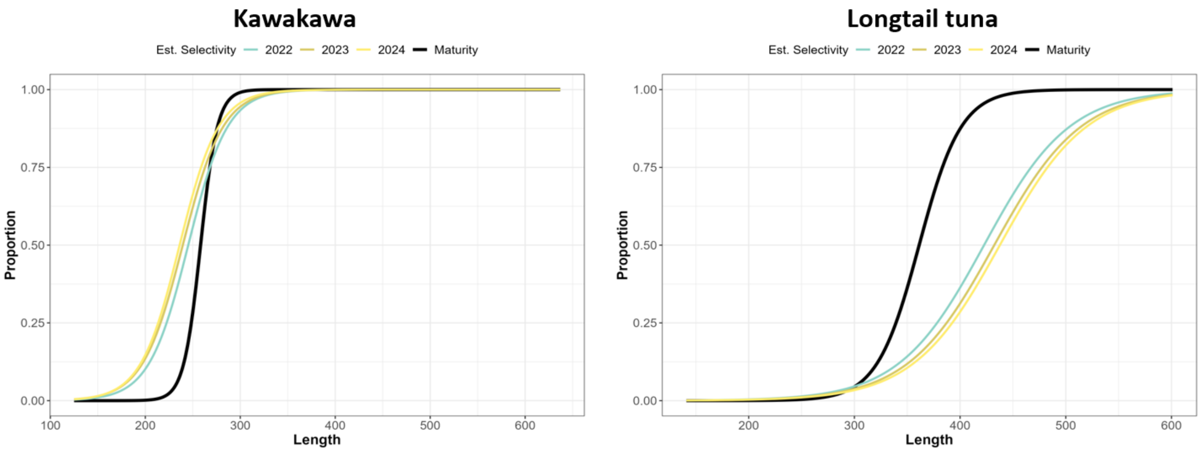

Figure 6 : Estimated selectivity curves for KAW and LOT from 2022 to 2024 based on LBSPR analysis

The estimated length at 50% selectivity (SL_{50}) provides insight into the size at which individuals of a species become vulnerable to capture by fishing gear. For *Euthynnus affinis* (kawakawa), the SL_{50} values declined slightly across the three-year period, from 248 mm in 2022 to 240 mm in 2023 and further to 237 mm in 2024. In contrast, *Thunnus tonggol* (longtail tuna) showed an increasing trend in SL_{50}, with values rising from 420 mm in 2022 to 430 mm in 2023 and 440 mm in 2024. The differences between species in SL_{50} are also notable. Kawakawa exhibited much lower SL_{50} values compared to longtail tuna, indicating that kawakawa are generally exposed to fishing mortality at smaller sizes. This has implications for their sustainability, as early selectivity can reduce the proportion of individuals that reach maturity and reproduce before capture.

3.5 Comparative Insights

Species differences were evident across all parameters, with longtail tuna exhibiting better overall condition and higher size-at-maturity but facing more severe reproductive decline by 2024. Gear type significantly influenced biological traits; purse seines captured broader size ranges and leaner fish, while trawls yielded fish with higher condition factors and more stable size structures. The yearly decline in condition and SPR highlights the urgent need for management interventions to protect spawning stocks, particularly for longtail tuna.

CONCLUSION

This study provides a comprehensive comparison of the biological parameters and reproductive potential of Euthynnus affinis (kawakawa) and Thunnus tonggol (longtail tuna) along the west coast of Peninsular Malaysia. The length-weight relationships indicated near-isometric growth in kawakawa and slightly negative allometric growth in longtail tuna, with strong correlations between length and weight for both species. Length frequency analysis showed that trawl gear generally captured larger, more uniform individuals, while purse seines yielded a broader size distribution, including juveniles. In terms of physical condition, longtail tuna consistently exhibited higher Fulton's K values compared to kawakawa, suggesting better somatic condition, possibly linked to species-specific physiology or energy allocation strategies. The two-way ANOVA confirmed that species significantly influenced condition factor, while gear type had no significant effect, reinforcing the robustness of biological assessments across gears.

Spawning potential ratio (SPR) analysis revealed a worrying decline in reproductive capacity, especially for longtail tuna, which saw SPR values plummet from 37% to 14% between 2022 and 2024, alongside increasing SL_{50} and elevated fishing mortality (F/M). Kawakawa also experienced declining SPR, though less severe. The contrasting SL_{50} trends—declining in kawakawa and increasing in longtail tuna—indicate differing responses to fishing pressure and gear selectivity. Overall, longtail tuna appear to face a greater risk due to delayed maturity and higher fishing mortality. These findings underscore the need for urgent management measures, such as gear selectivity improvements and size-based harvest controls, to sustain neritic tuna populations and protect their reproductive output. Continued monitoring of growth, condition, and SPR indicators is crucial to detect ecological shifts and to support evidence-based fisheries management in the region.

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