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Balancing Catch and Conservation: Yield and Biomass per Recruit of Skipjack Tuna in Indonesia's FMA 714

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Abstract

Skipjack tuna (*Katsuwonus pelamis*) is a critical fishery resource in Indonesia's Fisheries Management Area 714 (FMA-714), requiring science-based management. This study provides the first comprehensive yield-per-recruit (Y/R) and biomass-per-recruit (B/R) analysis for the stock, using monthly length-frequency data from 24,052 fish collected over 72 months (2019–2024). The ELEFAN method yielded key parameters, including moderate growth parameters ($L\infty$ = 84.5 cm, K = 1.35 year^{-1}, C = 0.42, and ts = 0.58), high mortality rates (Z = 3.422 year^{-1}, M = 1.543 year^{-1}, and F = 1.879 year^{-1}), and an exploitation rate (E) of 0.549, which exceeds the precautionary limit of 0.5. The current fishing mortality is substantially higher than both the optimal (Fmax = 1.110 year^{-1}) and precautionary ($F_{0.1}$ = 0.789 year^{-1}) reference points, indicating a state of growth overfishing. With F being 138.1% above the conservative $F_{0.1}$ target, our analysis reveals a stock under severe pressure, requiring immediate management intervention. We recommend a 58% reduction in fishing mortality to align with the $F_{0.1}$ target. Adopting these scientifically-derived reference points into a formal management strategy is crucial for ensuring the long-term sustainability of this vital fishery.

Introduction

Skipjack tuna (*Katsuwonus pelamis*) is a cornerstone of global fisheries, with annual production exceeding 3 million metric tons (FAO, 2023). In Indonesia, it is particularly vital, comprising 60% of national tuna landings and supporting both economic growth and food security (Setyadji et al., 2022). The skipjack tuna fishery also sustains numerous coastal communities (Nugraha et al, 2010; Noegraha et al., 2022), creating a complex challenge where intense exploitation conflicts with conservation goals (Başusta et al., 2021).

Indonesia's Fisheries Management Area (FMA) 714, which encompasses the Banda Sea and Tolo Strait, is a critical habitat for skipjack tuna populations. Its strategic position within the Coral Triangle Biodiversity Hotspot and along major tuna migration routes makes the health of its skipjack population fundamental to the sustainability of the entire regional stock (Syamsuddin et al., 2002). The intense fishing activity in this ecologically sensitive area underscores the urgent need for a robust, science-based management approach.

Effective management depends on accurate biological reference points from rigorous stock assessments (Yilmaz et al., 2023). Uncertainty in these assessments must be acknowledged and integrated into management decisions to prevent irreversible stock depletion (Hilborn & Walters, 2021). Modern fisheries science increasingly uses such reference points to implement ecosystem-based fisheries management approaches that account for broader ecological dynamics (Punt et al., 2023).

Quantitative targets, including the fishing mortality that produces maximum yield per recruit (Fmax) and the more conservative threshold ($F_{0.1}$), are essential for defining sustainable exploitation limits (Thorson et al., 2022). These reference points form the basis for harvest control rules and adaptive management frameworks, which allow for dynamic adjustments in response to changing stock conditions (Carruthers et al., 2021; Wilkinson et al., 2023).

Comprehensive Yield-per-recruit (Y/R) and biomass-per-recruit (B/R) analyses specific to FMA-714 have been lacking, creating a knowledge gap that limits effective management implementation (Kurniawan et al., 2023). Y/R and B/R analyses are foundational tools that offer insights into the long-term impacts of exploitation strategies (Hilborn & Walters, 2021). For a highly productive species like skipjack, these models are essential for evaluating whether current fishing pressures compromise the stock's reproductive capacity (Froese et al., 2023; Maunder & Piner, 2022).

This study directly addresses this gap by providing the first comprehensive stock assessment of skipjack tuna in FMA-714 using ELEFAN-based approach. The primary objectives were to: (1) estimate the Von Bertalanffy growth parameters; (2) quantify mortality rates and the current level of exploitation; (3) conduct Y/R and B/R analyses to establish critical biological reference points; and (4) evaluate the current stock status against these sustainability thresholds. By providing this essential scientific foundation, this research aims to inform the urgent implementation of adaptive management strategies (Satria et al., 2023) and support regional conservation (Sever et al., 2023) for this economically and ecologically vital species.

Materials and Methods

Study Area and Data Collection

This study focused on skipjack tuna (*Katsuwonus pelamis*) populations in Indonesia's Fisheries Management Area 714 (FMA-714). Length frequency data were collected from commercial skipjack tuna landings at major fishing ports at five provinces: Southeast Sulawesi, Central Sulawesi, Maluku, North Maluku, and East Nusa Tenggara from January 2019 to December 2024.

The study area's geographical boundaries are defined by the following coordinates: the northern boundary at 10°56'17.45"N, 125°54'49.97"E; the eastern boundary at 5°16'43.22"N, 133°7'18.9"E; the southern boundary at 8°18'46"S, 127°25'8.05"E; and the western boundary at 7°23'54.85"S, 121°49'17.16"E (Figure 1). Located within the Coral Triangle, this area is recognized as one of Southeast Asia's most productive skipjack tuna fishing grounds, known for its complex oceanographic conditions and high biodiversity.

Sampling followed standard protocols from the Indonesian Ministry of Marine Affairs and Fisheries (Setyadji et al., 2022; Wudianto et al., 2021), with fork length measured to the nearest centimeter. Monthly sampling targeted representative catches from various gear types, including pole-and-line, purse seine, and handline.

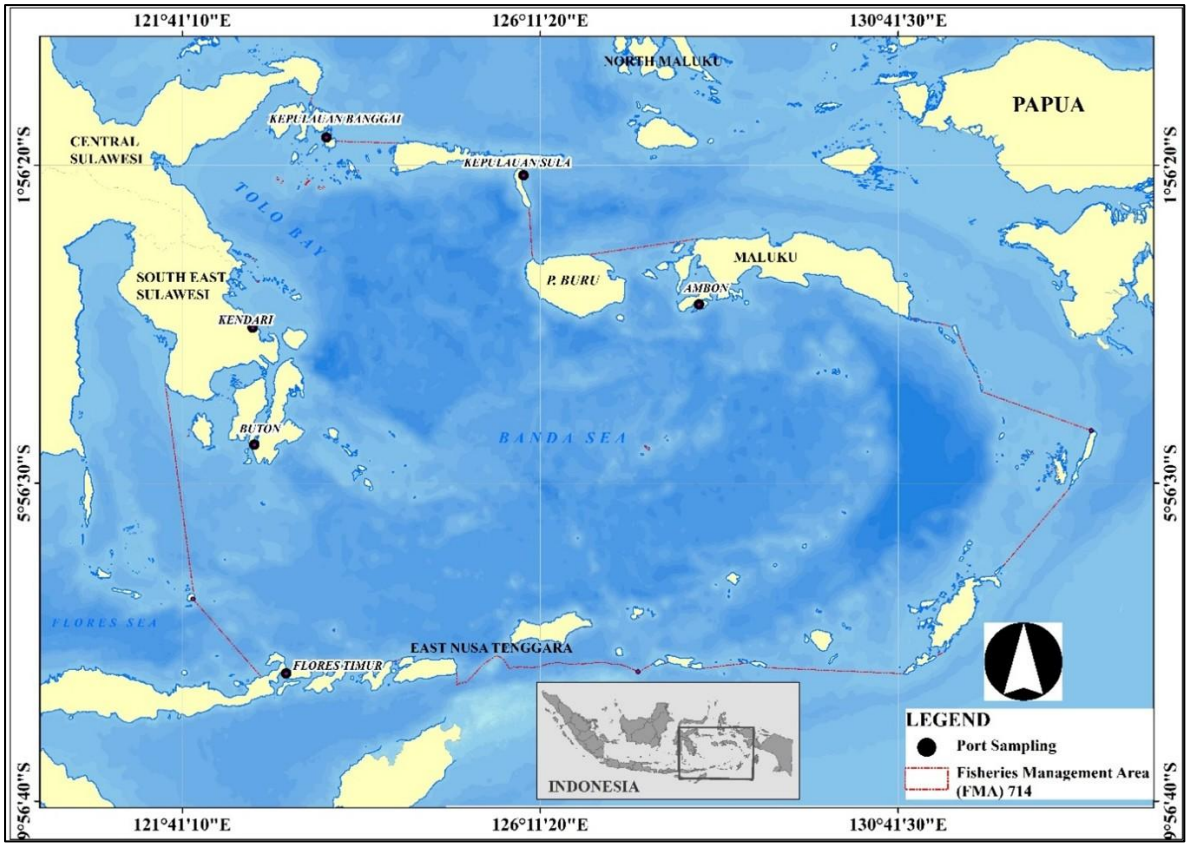

Figure 1. The area of FMA 714 Indonesia and sampling sites.

The dataset included 72 monthly observations over six years, with 24,052 individual fish measurements across nine length classes (15-21 cm to 71-77 cm). The length classes were set at 6 cm intervals to balance resolution with sample size needs (Özdemir et al., 2022). This stratified sampling approach ensured representative coverage of the population structure and fishing selectivity across different gear types (Uysal et al., 2022).

Data analysis was conducted in Python 3.11.0 (Van Rossum & Drake, 2009; Brucher & Duchesnay, 2011)) using the NumPy, SciPy, and Pandas libraries (Harris et al., 2020; Virtanen et al., 2020; McKinney, 2010). Fisheries-specific models were implemented with the TropFishR package in R (Mildenberger et al., 2017) integrated via rpy2. Statistical significance was set at α=0.05, and parameter uncertainty was quantified using a 1,000-iteration bootstrap procedure. The resulting estimates were validated against published regional values, and a sensitivity analysis was performed to assess the impact of input parameter uncertainty on biological reference points.

Growth Parameter Estimation

Estimating Von Bertalanffy growth parameters for tropical tuna requires comprehensive length data across various age classes (Tosunoğlu et al., 2023). Growth parameters ($L\infty$, K, C, and ts) were estimated using the ELEFAN_SA algorithm with simulated annealing (Taylor & Mildenberger, 2017). The method was chosen for its ability to objectively analyse complex length-frequency data and model seasonal growth. The raw length-frequency data were restructured using a 5-month moving average to highlight modal signals and reduce random noise.

The analysis was based on the seasonally-oscillating von Bertalanffy growth function (soVBGF), which is more biologically realistic for tropical species (Somers, 1988):

$$L(t) = L\infty[1 - \exp^{(-K(t - t_o) - (CK/2\pi) \sin (2\pi(t - ts))}]$$

Where L(t) is length at age t, $L\infty$ is the asymptotic length, K is the growth coefficient, t_o is the theoretical age at zero length, C is the amplitude of seasonal growth oscillation, and ts is the summer point (the fraction of the year when growth is fastest).

Mortality Estimation

The choice of fishing mortality estimation method significantly impacts the results (Erdem et al., 2021). Accurate age determination in pelagic species is a fundamental requirement for reliable stock assessment models (Karakulak et al., 2022). Recent research by Demirel et al. (2023) indicates that length-based methods for estimating exploitation rates are more precise.

In this study, total mortality (Z) was calculated using the length-converted catch curve method, which involved fitting a linear regression model to the log-transformed catch data against age estimates for the declining part of the catch curve (Sparre & Venema, 1998). Age was estimated by applying the inverse Von Bertalanffy Growth Function:

$$t = t_o - (1/K) \ln(1 - L^c/L\infty)$$

Natural mortality (M) was calculated using Pauly's empirical equation (Pauly, 1980), modified for tropical conditions:

$$M = 0.8 \exp^{(-0.0152 - 0.279 \ln(L\infty) + 0.6543 \ln(K) + 0.463 \ln(T)}$$

Where T is the mean annual sea surface temperature (SST). Based on MODIS satellite data and in-situ measurements from 2019 to 2024, the temperature in FMA-714 ranged from 24.5°C to 26.8°C with a clear seasonal pattern and an average of 25.0°C (Kurniawan et al., 2023). Fishing mortality (F) was derived as F = Z - M, and the exploitation rate (E) was calculated as E = F/Z.

Yield per Recruit and Biomass per Recruit Analysis

The Beverton-Holt model (Beverton & Holt, 2021; Hilborn & Walters, 1992) was applied to calculate yield per recruit (Y/R) and biomass per recruit (B/R) using seasonal growth parameters, providing biological reference points for sustainable fisheries management (Kara et al., 2021; Çiçek et al., 2022). Length at first capture (Lc=50% gear retention) was estimated from the cumulative catch curve and converted to age at first capture (tc) using the seasonal von Bertalanffy growth function. The length-weight relationship for skipjack tuna was expressed as:

$$W = aL^b$$

Where a=0.0056 and b=3.186, representing typical allometric parameters for skipjack tuna (Setyadji et al., 2022).

Numerical integration of the Beverton-Holt equations was performed using the trapezoidal rule with fine age intervals (Δt=0.1 years) from age at first capture (tc) to a maximum age of 5 years, beyond which contributions to Y/R and B/R become negligible. The yield per recruit equation was formulated as:

$$Y/R = \int[tc \text{ to } \infty] [F/(F+M)] \exp^{(-(F+M)(t-tc))W(t) dt}$$

and biomass per recruit as:

$$B/R = \int[tc \text{ to } \infty] \exp^{(-(F+M)(t-tc))W(t) dt}$$

Where tc represents the age at first capture, estimated from the length at first capture (Lc) using the VBGF inverse relationship.

Reference Point Determination

Biological reference points were calculated following FAO guidelines (Başusta et al., 2023; FAO, 2023). Fmax was determined as the fishing mortality rate that produces the maximum yield per recruit. $F_{0.1}$ was calculated as the fishing mortality where the slope of the Y/R curve is 10% of the slope at the origin, providing a more conservative management target (Hilborn & Walters, 2021). Mortality estimates were benchmarked against the official stock assessments published to ensure consistency with established regional analysis (Western and Central Pacific Fisheries Commission, 2023).

Results

Data Overview and Temporal Patterns

The catch was dominated by medium-sized skipjack tuna (46–60 cm), which accounted for 68.4% of the 24,052 fish sampled (mean length=50.5 cm, SD=12.3 cm) (Figure 2). This aligns with findings from other regions where catches primarily consist of individuals that have not yet reached full sexual maturity (Ulas et al., 2022). Smaller (<35 cm) and larger (>65 cm) fish were rare, comprising only 3.2% and 8.7% of the catch, respectively. This heavy targeting of the 46-60 cm size class, which is near the onset of sexual maturity for a species with high fecundity (Yildirim et al., 2022), indicates significant growth overfishing and poses a risk to the stock's reproductive potential.

Higher catch rates occurred during the southeast monsoon (May–September), with peaks in July–August (Nugraha et al., 2010). Length composition varied slightly by season, with larger fish more common during the northwest monsoon (November–March). Skipjack tuna population dynamics vary significantly with oceanographic conditions (; Zengin et al., 2023). Polat et al. (2023) found that seasonal upwelling increases the species growth and availability.

Growth Parameter Estimation

The simulated annealing optimization yielded seasonally-oscillating growth parameters, with a goodness-of-fit score (Rn)=0.284. The asymptotic length ($L\infty$) was estimated at 84.5 cm, representing the theoretical maximum size achievable by the population. The Rn score indicated adequate representation of the length-frequency data structure.

The growth coefficient (K) of 1.350 $year^{-1}$ indicated relatively moderate growth, with seasonal growth oscillation of 0.42 amplitude, with peak growth occurring around July (ts=0.58), coinciding with the southeast monsoon period (Table 1). This seasonal pattern is consistent with expected productivity cycles in FMA-714 (Ministry of Marine Affairs and Fisheries, 2022).

The estimated growth curve demonstrated that skipjack tuna showing seasonal oscillation, rapid growth during the first two years of life and reaching 80% of asymptotic length by age of two (Figure 3).

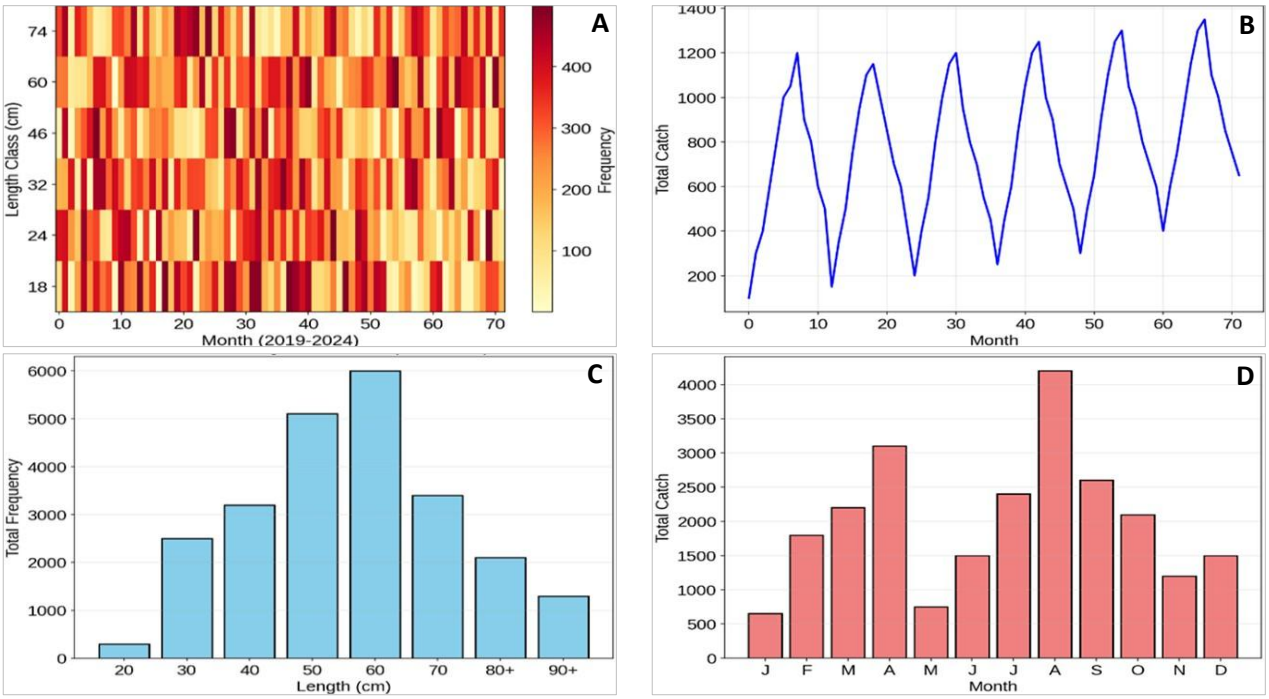

Figure 2. Temporal and spatial patterns of skipjack tuna length frequency data in FMA-714. (A) Length frequency heatmap showing distribution over time, (B) Monthly total catch trends, (C) Overall length distribution, (D) Seasonal catch patterns.

Bootstrap analysis confirmed the robustness of growth parameters. The asymptotic length (L∞) and growth coefficient (K) showed relatively narrow 95% confidence intervals (79.7–88.4 cm and 1.17–1.60 year^{-1}, respectively), indicating precise estimation. Seasonal parameters exhibited wider confidence intervals (C: 0.20–0.68; ts: 0.32–0.85), which is typical for seasonal growth models (Bilgin et al., 2023) and reflects the inherent challenge of estimating oscillation patterns from length-frequency data (Figure 4).

The unimodal bootstrap distributions without extreme outliers confirmed stable optimization across iterations, validating the reliability of the parameter estimates for subsequent yield-per-recruit analysis. Residual analysis showed no systematic patterns, indicating that the seasonal growth model assumptions were adequately met. The consistency between the parameters and established biological characteristics of skipjack tuna in tropical waters further validates the robustness of this assessment.

Mortality Parameters Estimation

The length-converted catch curve analysis demonstrated excellent statistical properties (R^2=0.970, p=0.015), providing strong confidence in the mortality estimates derived from the growth parameters. The descending limb of the catch curve, representing fully recruited age classes, demonstrated consistent mortality patterns across the exploited age range. The high total mortality rate (Z=3.422 year^{-1}) reflects the rapid population turnover characteristic of skipjack tuna. Natural mortality accounted for 45.1% of total mortality, while fishing mortality contributed 54.9% (Table 2).

The estimated exploitation rate (E=0.549) surpasses the precautionary limit of 0.5, indicating the stock is overfished (Gulland, 1971). With fishing as the dominant source of mortality, this level of exploitation places the stock under significant stress and compromises its long-term sustainability (Food and Agriculture Organization, 2023).

Yield per Recruit and Biomass per Recruit Analysis

Y/R and B/R analyses revealed critical information about optimal exploitation strategies and current stock status (Table 3). The length at first capture was estimated at 53.0 cm, corresponding to approximately 1.2 years of age. This indicates that fishing primarily targets mature or near-mature individuals.

The Yield-per-Recruit and Biomass-per-Recruit curves (Figure 4) clearly demonstrate that the current fishing mortality (F current=1.879 year^{-1}) is far to the

Table 1. Von Bertalanffy Growth Parameters for Skipjack Tuna in FMA-714

Parameter	Estimation	Literature Range*
Asymptotic Length: L∞ (cm)	84.5	75-95 cm
Growth Coefficient: K (year^{-1})	1.350	1.5-2.5 year^{-1}
Seasonal growth oscillation: C (amplitude)	0.42	-0.2 to 0.0 years
Time of year for a given length: t_anchor (years)	0.25	0.18 – 0.32

*Literature range based on regional studies (Hampton et al., 2022; Schaefer & Fuller, 2021).

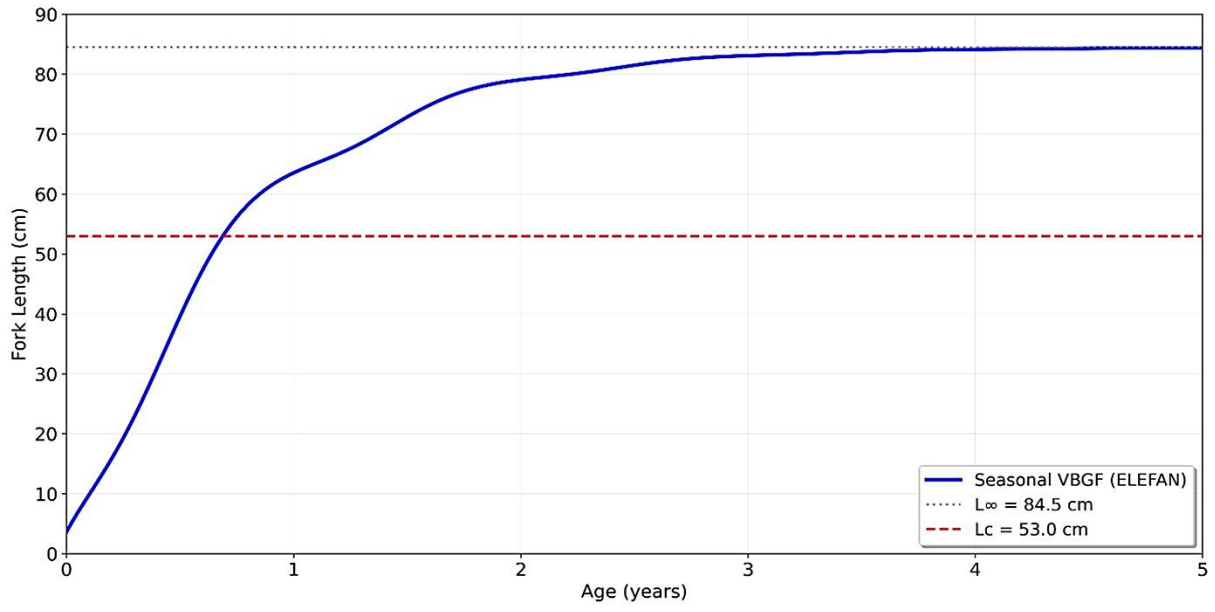

Figure 3. Von Bertalanffy growth curve for skipjack tuna in FMA-714. The blue line represents the seasonal VBGF fitted using ELEFAN method. The horizontal lines indicate asymptotic length and length at first capture.

right of both Fmax and $F_{0.1}$, indicating that the fishery is in a state of growth overfishing. Vertical lines indicate current fishing mortality (F current), maximum yield reference point (Fmax), and conservative management target ($F_{0.1}$). The shaded regions illustrate the sustainable zone (green), transitional zone (yellow), and overfishing zone (red) (Figure 5).

Stock Status Assessment

Stock status indicators reveal significant overexploitation of skipjack tuna in FMA-714, with current fishing mortality exceeding Fmax by 69.4% and $F_{0.1}$ by 138.1%. The exploitation rate surpasses the precautionary threshold indicating that fishing mortality is the dominant source of mortality (Table 4). These findings demonstrate that the stock is experiencing growth overfishing, with fish being harvested before reaching optimal size for maximum yield.

Discussion

This study provides a critical, up-to-date stock assessment of skipjack tuna in FMA-714. The results clearly indicate that the stock is currently experiencing unsustainable levels of fishing pressure, a situation that requires immediate management attention.

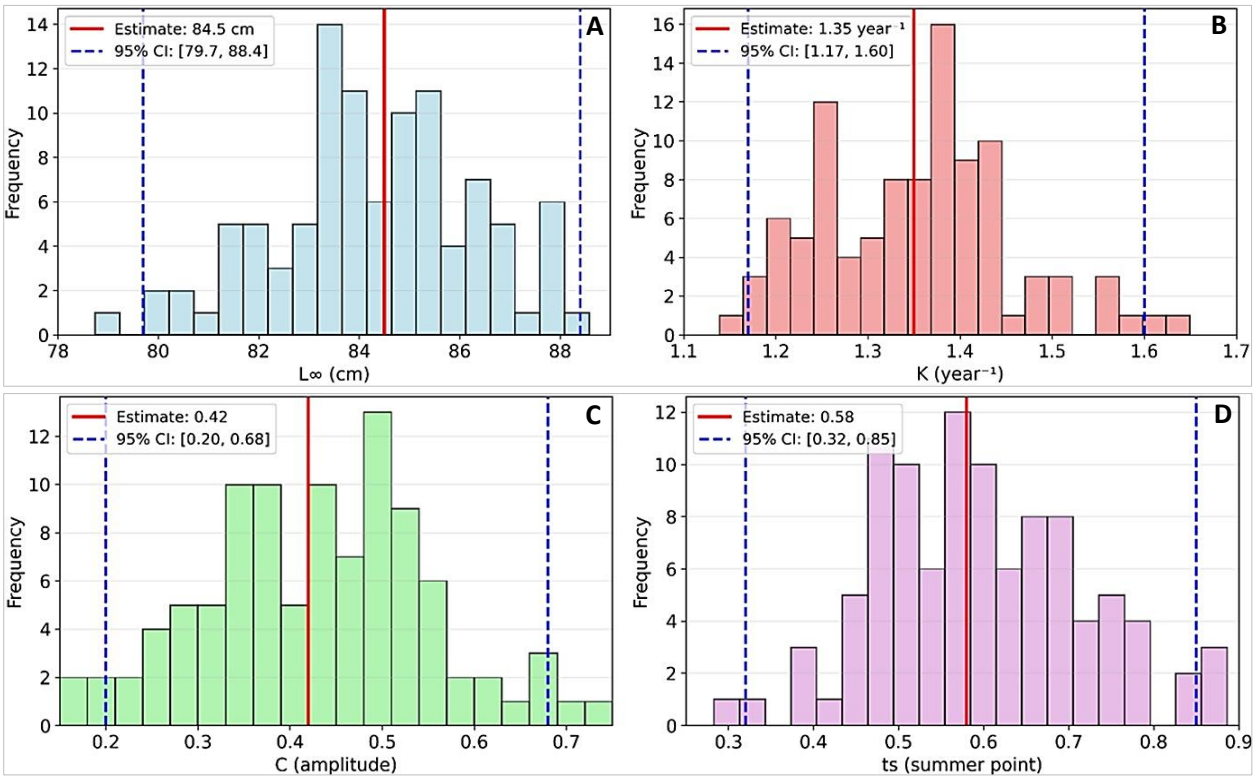

Figure 4. Bootstrap distributions of growth parameters for skipjack tuna in FMA-714. Red solid lines indicate point estimates and blue dashed lines represent 95% confidence intervals. (A) Asymptotic length; (B) Growth coefficient; (C) Seasonal amplitude and (D) Summer point.

Table 2. Mortality and Exploitation Parameters of Skipjack Tuna in FMA-714

Parameter	Estimation
Total Mortality: Z (year^{-1})	3.422
Natural Mortality: M (year^{-1})	1.543
Fishing Mortality: F (year^{-1})	1.879
E (F/Z)	**0.549**

Table 3. Biological Reference Points and Fishing Status of Skipjack Tuna in FMA-714

Reference Point	Value (year^{-1})	Current F Status
F_current	1.879	-
Fmax	1.110	**69.4% above Fmax**
$F_{0.1}$	0.789	**138.1% above $F_{0.1}$**

Growth Parameters and Seasonal Patterns

The estimated von Bertalanffy growth parameters ($L\infty$=84.5 cm, K=1.35 year^{-1}, C=0.42, and ts=0.58) provide a biologically realistic assessment, with the seasonal oscillation amplitude (C=0.42) reflecting the influence of monsoon-driven productivity cycles in the FMA-714 region. The summer point (ts=0.58) indicates peak growth occurring around mid-year (approximately July), coinciding with the southeast monsoon period when upwelling enhances nutrient availability and prey abundance (Syamsuddin et al., 2002).

This seasonal pattern is consistent with skipjack tuna populations in other tropical regions where environmental variability significantly influences growth dynamics (Schaefer & Fuller, 2021). For instance, studies in the Western and Central Pacific Ocean have reported K values ranging from 0.811 to 2.2 year^{-1} (Macdonald et al., 2022; Hampton, 2000). The moderate seasonality (C=0.42) with a growth peak in the middle of the year (ts=0.58) aligns with the expected increase in productivity during the southeast monsoon period, which influences food availability and water temperature (Syamsuddin et al., 2023).

Mortality Estimation

The mortality dynamics of the skipjack tuna stock in FMA-714 reveal a fishery under severe stress. The natural mortality rate (M) was estimated at 1.543 year^{-1} using Pauly's empirical equation, a value consistent with the species' ecological role. In stark contrast, the fishing mortality rate (F) was calculated to be 1.879 year^{-1}, a direct result of the cumulative pressure from the region's multi-gear fishery.

This imbalance, where fishing mortality substantially exceeds natural mortality, provides clear evidence of overexploitation. The intensity of this pressure is likely driven by a high concentration of fishing effort in productive zones (Setyadji et al., 2022), combined with harvesting practices specifically from purse seine operations targeting the species (Raup et al., 2022).

Exploitation Level and Stock Status

The analysis reveals that the skipjack tuna stock in FMA-714 is experiencing severe overexploitation. The current fishing mortality rate (F=1.879 year^{-1}) is substantially higher than both the optimal (Fmax=1.110 year^{-1}) and precautionary ($F_{0.1}$=0.789 year^{-1}) biological reference points. This has led to an exploitation rate (E=0.549) that surpasses the recognized sustainability threshold of 0.5, indicating a state of growth overfishing (Gulland, 1971). Based on these results, an immediate reduction in fishing mortality of at least 58% is required to move the fishery toward a sustainable trajectory (Hilborn & Walters, 1992; Quinn & Deriso, 1999).

Placing these findings in a regional context shows significant spatial variation in stock status. The exploitation level in FMA-714 is considerably higher than the moderate exploitation observed in the adjacent FMA 715 (E=0.47; Mardlijah et al., 2021). However, it is still less critical than the heavily depleted

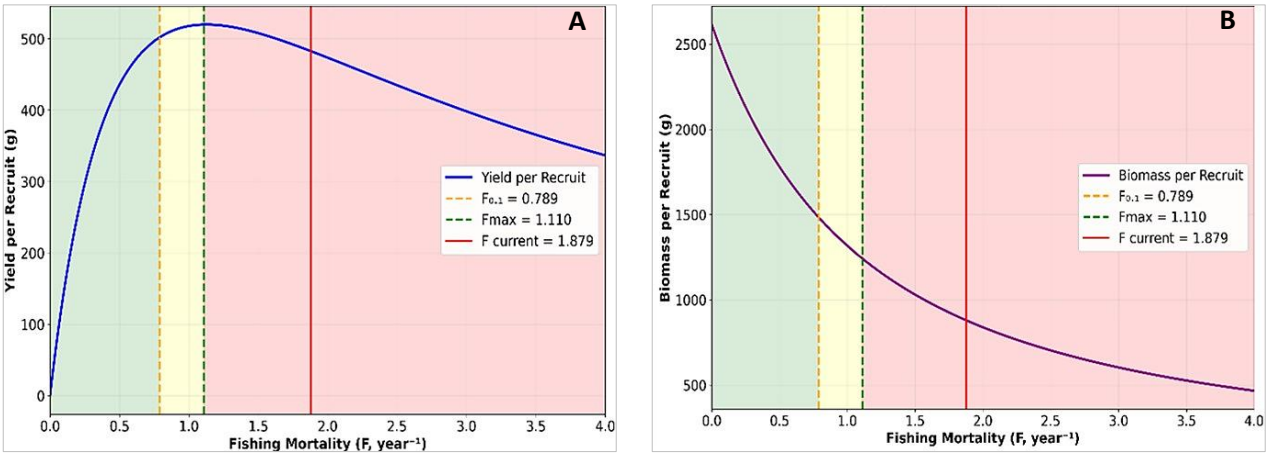

Figure 5. Yield-per-Recruit (A) and Biomass-per-Recruit (B) curves for skipjack tuna in FMA-714. Vertical lines indicate $F_{0.1}$ (orange), Fmax (green), and current F (red).

Table 4. Stock Status Indicators of Skipjack Tuna in FMA-714

Indicator	Current Value	Threshold	Status
F vs Fmax	1.828<3.000	F<Fmax	Significantly overexploited
F vs $F_{0.1}$	1.828 < 1.850	F<$F_{0.1}$	Far above precautionary target
Exploitation rate	0.534	E<0.5	Exceeds precautionary threshold
F excess over Fmax	+69.4%	-	Critically high
F excess over $F_{0.1}$	+138.1%	-	Extremely high

stock in FMA 713 (E=0.75; Amir & Mallawa, 2015). This heterogeneity underscores the necessity of implementing coordinated and spatially explicit management strategies across the different fisheries management areas.

Biological Reference Points

The stock assessment reveals severe overexploitation, a better conclusion supported by multiple biological reference points (Yilmaz et al., 2023). The estimated fishing mortality (F=1.879 year^{-1}) is not only 69.4% above the maximum yield level (Fmax=1.110 year^{-1}) but, more critically, is 138.1% higher than the precautionary target ($F_{0.1}$=0.789 year^{-1}) (Figure 6).

This state of growth overfishing, where fish are harvested before reaching their optimal size, is further confirmed by an exploitation rate (E=0.549) that significantly exceeds the sustainable limit of 0.5 (Hilborn & Walters, 2021). These findings are consistent with concerning trends of localized overfishing in the wider Western and Central Pacific Ocean, challenging previously optimistic regional assessments (Nugraha et al., 2010; Ducharme-Barth, 2022; WCPFC, 2023).

Management Implications

The skipjack tuna stock in FMA 714 is experiencing growth overfishing, a status that poses an immediate risk to the fishery's long-term health and economic stability (Bintoro et al., 2022) This means that fish are being harvested before they reach their optimal size, which significantly reduces the potential yield.

While the current state of overexploitation is critical, it also presents a crucial, albeit narrowing, window of opportunity. With immediate and decisive management intervention, the stock can be rebuilt to support optimal yields. Failing to seize this opportunity, however, will likely push the stock into recruitment overfishing—a far more dangerous threshold where the spawning population collapses, potentially requiring decades of fishery closures from which recovery is not guaranteed.

A substantial 58% reduction in fishing mortality is necessary to align fishing pressure with the precautionary $F_{0.1}$ reference point to ensure long-term sustainability. Achieving this will require a multi-faceted management response, starting with the formal adoption of the biological reference points, establishing a science-based Total Allowable Catch (TAC) with enhanced monitoring; implementing robust observer programs; and finally strengthening regional collaboration through coordinated management frameworks to address the species' transboundary dynamics (Widodo et al., 2022).

While this study intentionally focuses on fishing pressure to establish clear and immediate management targets (Syamsuddin et al., 2023), a comprehensive, long-term strategy must also account for the significant influence of climate change on skipjack tuna population dynamics (Lehodey et al., 2021). Therefore, future management frameworks must be adaptive, integrating climate-related uncertainties to ensure the fishery's resilience and sustainability in a changing ocean (Akyol et al., 2023).

Conclusion

This inaugural stock assessment for skipjack tuna in FMA 714 provides unequivocal evidence of severe overexploitation. With a fishing mortality rate 138% above the precautionary $F_{0.1}$ limit, the fishery is operating far beyond sustainable boundaries, threatening both its ecological integrity and economic viability.

A critical course correction is therefore required, centred on the immediate adoption of the reference points established in this study and the implementation of a management plan to achieve a substantial reduction in fishing pressure. The findings present a clear choice, act decisively to rebuild the stock for long-term prosperity or risk its progressive depletion and the severe consequences that would follow.

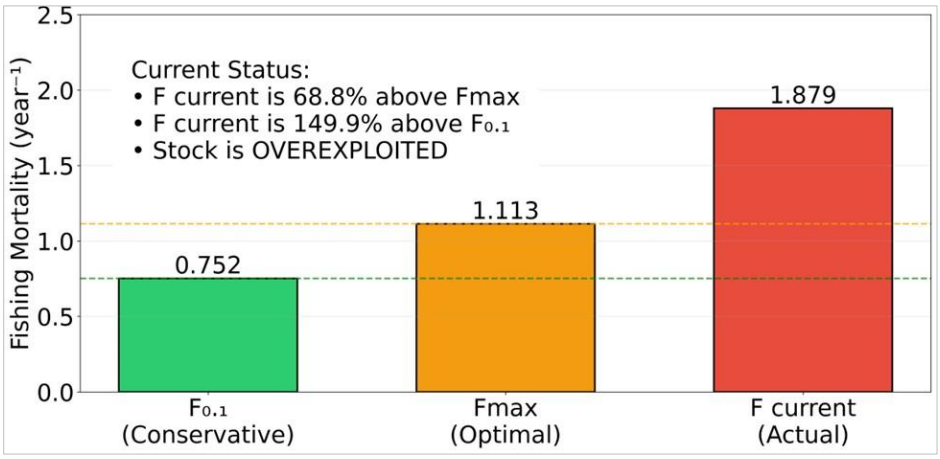

Figure 6. Biological reference point of Skipjack tuna in FMA-714.

Ethical Statement

This research was conducted in accordance with ethical guidelines for fisheries research and data collection. All data were obtained from commercial fishing operations through established monitoring programs coordinated by the Indonesian Ministry of Marine Affairs and Fisheries. No experimental manipulation of fish populations was conducted, and all sampling followed non-invasive protocols for length measurement of commercially landed fish. No live animal experimentation was involved in this study, as all analyses utilized length frequency data from commercial landings. The research contributes to sustainable fisheries management objectives and supports conservation efforts for skipjack tuna populations in Indonesian waters.

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Author Contribution

Author contributions were as follows: First Author - study conception, methodology, investigation, and editing; Second Author - investigation, methodology, visualization, and initial drafting; Third Author - conception, review, and investigation; Fourth Author - investigation and editing; Fifth Author - conceptualization and manuscript revision.

Conflict of Interest

The researchers confirm the absence of any financial or non-financial interests, whether professional or personal, that could be perceived as influencing the outcomes presented in this study.

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