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Morpho-biology of *Pomadasys auritus* from bottom longline catches in Tarakan waters, North Kalimantan, Indonesia

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Abstract. *Firdaus M, Ibrahim AJ, Salim G, Haryono MG, Bija S, Girsang NR, Mujiyanto M, Hartinah S, Hartati R, Rozi. 2025. Morpho-biology of* Pomadasys auritus *from bottom longline catches in Tarakan waters, North Kalimantan, Indonesia. Biodiversitas 26: 5870-5880. Pomadasys auritus* is an economically important demersal species in Tarakan waters, yet the biological information required for effective stock management remains limited. This study describes the morphological characteristics and estimates the growth parameters of *P. auritus* captured by bottom longlines. Sampling was conducted from November 2022 to February 2023 at the Selumit Landing Site, yielding 219 specimens across 16 fishing trips. Morphological identification was based on diagnostic opercular traits, fin-ray formulas, and body colouration. Growth parameters were estimated using the von Bertalanffy Growth Function (VBGF), resulting in an asymptotic length (L_∞) of 109.53 cm, a growth coefficient (K) of 0.0194 day^{-1}, and a theoretical age at zero length (t_0) of 0.823 days. These values indicate slow growth and a tendency to reach large body sizes, traits characteristic of long-lived demersal fishes that are naturally susceptible to fishing pressure. The catch composition, dominated by sub-adult and adult individuals, suggests that Tarakan waters serve as an important habitat supporting the growth phase of this species. This pattern underscores the need for cautious management, particularly because slow-growing species are vulnerable to rapid stock depletion under sustained exploitation. The dataset generated in this study provides an essential biological baseline that can support more accurate stock assessments and inform the development of appropriate management strategies for demersal fisheries in northern Kalimantan. Given that the dataset is derived solely from landing-site observations, future studies should incorporate reproductive biology, feeding ecology, environmental conditions, and mortality parameters to enhance population models and strengthen the scientific basis for managing *P. auritus* in Tarakan waters.

Keywords: Age estimation, demersal fish, growth coefficient, javelin grunt, Tarakan waters

INTRODUCTION

Tarakan Island, located in North Kalimantan, Indonesia, is bordered by coastal waters that support productive demersal fisheries, which are essential to local food security and livelihoods. Although studies at the global scale show that demersal fish communities are susceptible to fishing pressure and habitat disturbance (Greenstreet et al. 2012; Mak et al. 2021; MacNeil et al. 2025), the main challenge in Tarakan is the limited availability of biological information for the species most heavily exploited by local fishers. Similar issues have been noted in other Indonesian waters, where increasing human activities and habitat degradation continue to threaten demersal resources (Syam et al. 2023). In Tarakan, important groups such as snappers (*Lutjanus* spp.), groupers (*Epinephelus* spp.), and the javelin grunt (*Pomadasys auritus* (Cuvier, 1830)) inhabit muddy-sandy substrates influenced by tidal dynamics. Among these species, *P. auritus*, locally known as *arut* or *gerot-gerot*, is a primary target of bottom longline fisheries and has considerable economic value in the local demersal fishery (Indarjo et al. 2020a). Despite this importance, detailed biological information on *P. auritus* remains unavailable for Tarakan waters, limiting the accuracy of stock assessments and the development of effective management strategies.

Bottom longline fisheries are the most widely used gear in Tarakan and remain a primary source of livelihood (Jabarsyah et al. 2022; Al-Hafidz et al. 2024). Their increasing intensity and mechanisation, together with the use of mini-trawls, have increasingly affected local fish stocks (Salim et al. 2023a, 2023b). Bottom longlines target high-value demersal species (Firdaus and Kamelia 2011; Firdaus et al. 2020), including *P. auritus*. Although several studies have examined "arut fish" in Tarakan (Firdaus et al. 2021a; 2021b), these studies only identified the fish at the genus level (*Lutjanus* spp.) and did not provide species-specific biological information on *P. auritus.* This gap further highlights the lack of accurate morphological and biological data for this key demersal species.

Research on *P. auritus* has provided insights into morphology, growth, reproduction, and diet across regions. In Indonesia, studies near Tarakan examined size composition, length-weight relationships, condition indices, and first capture size (Firdaus et al. 2021a; Salim et al. 2023a, 2023b). Research on *Pomadasys* spp. has advanced regionally and globally, covering morphology, diet, and reproduction. Indonesian studies near Tarakan have examined general size structure and maturity patterns (Firdaus et al. 2021a; Salim et al. 2023a, 2023b), but no study has yet provided species-specific diagnostic traits or growth parameter information for *Pomadasys auritus* in Tarakan waters. Meanwhile, international studies on *P. kaakan* (Hata et al. 2015; Annisa et al. 2018), *Pomadasys stridens* (Osman et al. 2019; Avşar et al. 2021; Akalın et al. 2025), *P. jubelini* (Olopade et al. 2020), and *Pomadasys argenteus* (Uehara et al. 2025) illustrate the ecological diversity within the genus. However, these findings cannot be directly applied to Tarakan's population because environmental characteristics, fishing intensity, and ecological conditions differ, requiring site-specific assessments. Previous applications of the von Bertalanffy model in nearby regions (Salim et al. 2020a, 2021, 2022, 2023b, 2024; Indarjo et al. 2022) offer general growth insights, but none address the ecological uniqueness of *P. auritus* in Tarakan, highlighting a critical site-specific data gap.

Information on morphology and growth is fundamental for understanding population biology (Perdana et al. 2016; Salim et al. 2021), and supports management decisions, sustainable utilization, and the prevention of stock decline (Salim et al. 2020a; Salim et al. 2020b). Morphological traits also indicate population adaptation and help maintain diversity and productivity (Ahmad et al. 2025), while studies on benthic fishes show that morphological variation reflects ecological niches and habitat use (Endo and Watanabe 2020). Effective management further requires precautionary approaches (Salim et al. 2023a) that ensure community benefits (Ghosh 2014). This study aimed to describe the morphological characteristics and estimate the growth parameters of *P. auritus* captured by bottom longlines. Therefore, detailed, species-specific data on the morphology and biology of *P. auritus* are crucial for producing accurate stock assessments and supporting sustainable management of demersal fisheries in Tarakan, North Kalimantan, Indonesia.

MATERIALS AND METHODS

Sampling location

This study was conducted in the Tarakan fishery region, North Kalimantan, Indonesia. Sampling of bottom longline landings was carried out at the Selumit Fish Landing Place (FLP), Tarakan (3°17'53.86" N 117°34'42.23" E). Laboratory measurements were performed at the Fisheries Biology Laboratory, Faculty of Fisheries and Marine Science, Universitas Borneo Tarakan, Indonesia. Sampling covered four months (November 2022-February 2023) across 16 events at roughly biweekly intervals. This period was selected because bottom-fishing activity in Tarakan typically peaks, thereby increasing the likelihood of capturing a more complete range of individual sizes.

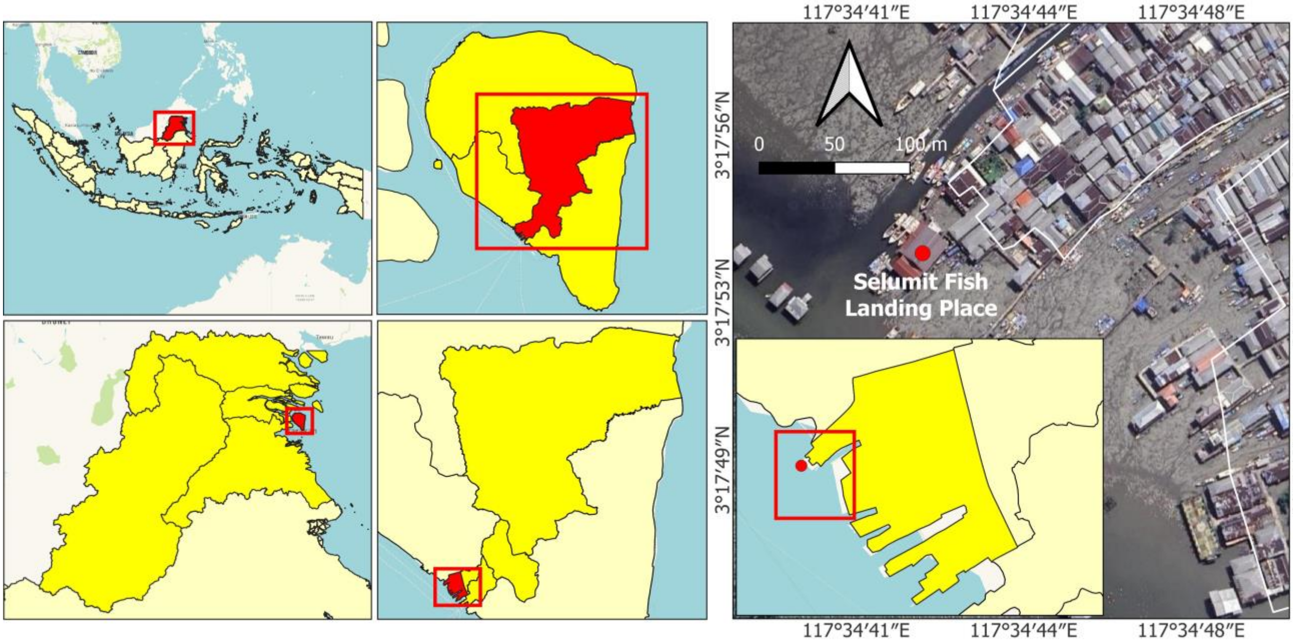

Figure 1. Sampling location at the Selumit Fish Landing Place (FLP), Tarakan, North Kalimantan, Indonesia

Ethics statement

All specimens analysed were obtained from commercial landings, no fish were sacrificed expressly for this research. Handling and measurements followed good practice to minimise specimen damage and ensure data quality. No protected species were intentionally sampled.

Sampling design

Specimens were collected opportunistically at landing-sites from bottom-longline catches that included *P. auritus*. When large quantities of fish were landed, a representative subsample covering the full length range was taken to avoid over-collection. We also preferentially sampled during neap tides, when local longline landings were most active and the demersal assemblage was relatively stable (Brogan 2002). At each event, approximately 20 kg of catch was sub-sampled; all retained individuals were enumerated, yielding n = 219 *P. auritus* for the study.

Although the present study relied on a fisheries-dependent sampling approach using landed catches from local fishers, this method may not fully capture the complete population structure of *P. auritus*, particularly individuals that are discarded or never landed. The bottom line used by local fishermen consists of a central line with a diameter of approximately 3-5 mm, a lateral line with a length of approximately 30-50 cm, a weight of 1-2 kg, a float, and a hook size 9-11 (equivalent to the international standard size 1-1/0), with an average soak time of 2-4 hours before removal.

Morphological characterization

Species identification and morphological characterization followed standard ichthyological practices for meristic and morphometric traits (Hata et al. 2015). Diagnostic external characters included overall body form, fin formulas (dorsal, anal, and pectoral) as described by Basuonie et al. (2020), as well as lateral-line scale counts, gill-raker counts, and coloration patterns (Nader et al. 2024). Measurements were taken using a digital calliper (to the nearest 0.01 cm) and expressed as absolute values and as proportions of Standard Length (SL). To strengthen species confirmation, several key diagnostic traits were applied, including dorsal fin composition of XI spines and 13-15 soft rays (D XI+13-15), 48-52 lateral-line scales, 16-20 gill rakers, a more distinctly sloping head profile, and a yellowish body coloration with faint but more clearly defined dark bands.

For each specimen, we recorded Total Length (TL), Standard Length (SL), Fork Length (FL), Head Length (HL), Body Depth (BD), Body Width (BW), and Whole-body weight (W). Linear measurements were taken to 0.1 mm using calibrated digital callipers, and weights to 0.01 g on an analytical balance. To avoid measurement bias, individuals with deformities or bent limbs were excluded from all analyses (Sparre and Venema 1998).

Growth analysis

Growth was modelled with the Von Bertalanffy Growth Function (VBGF), which is widely adopted in tropical fisheries because its parameters are biologically interpretable and can be estimated from length-frequency data when direct ageing is unavailable (Pauly 1984; Sparre and Venema 1998).

$$L_t = L_\infty \left(1 - e^{1K(t-t_0)}\right)$$

Where:
Lt : Fish length at age t (cm)
L∞ : Infinitive length (cm)
K : Growth coefficient (per day)
t0 : Estimated theoretical age of fish at zero length

Estimation of L_∞ and K followed the Gulland and Holt (1959), length-increment approach from successive samples, regressing the observed growth increment $\Delta L/\Delta t$ on mean size $\frac{L_t+L_{t+\Delta t}}{2}$; linear fit yields $L_\infty = -a/b$ and $K = -b$ (Pauly 1984; Sparre and Venema 1998). The t_0 parameter was obtained from Pauly's empirical equation, a pragmatic estimator commonly applied when hard parts for ageing are not collected (Pauly 1984). Lengths were binned into 1-cm classes across the 16 sampling events. Calculations and model fitting were performed using FiSAT II software with Length Frequency Analysis (ELEFAN-II) (Gayanilo et al. 2005; Damora et al. 2021) and verified in Microsoft Excel to ensure computational accuracy and reproducibility. Included only specimens with complete measurements in the analysis.

The growth coefficient KK was first expressed in day^{-1} to match the temporal resolution of the sampling intervals and then converted to year^{-1} using $K_{yr^1} = K_{day^1} \times 365.25$ for comparability with previous research. Examined estimated L_∞ values relative to the maximum observed sizes in the dataset to ensure that the asymptotic length remained biologically reasonable for *P. auritus* and consistent with known species size ranges.

Assumptions of the model included a locally closed population during the sampling window, relatively stable recruitment between November and February, and minimal measurement error relative to the 1-cm bin width (Sparre and Venema 1998). Reproduced calculations in spreadsheets and cross-checked using open routines for length-frequency analysis, ensuring transparent and repeatable workflows for data-limited fisheries (Mildenberger et al. 2017). To evaluate robustness, sensitivity analyses were performed by re-binning length data into 0.5-cm intervals, repeating the estimation after excluding early and late sampling events (boundary checks), and reassessing parameter stability under these modified datasets. These tests showed minimal variation in L_∞, K, and t_0, indicating that the growth model remained stable across the various analytical conditions. Although the VBGF provides a valid approximation of growth, its interpretation must consider ecological variability in dynamic coastal ecosystems, such as in Tarakan.

Units, assumptions, and sensitivity checks

The growth coefficient K is first expressed in day^{-1} (reflecting sampling resolution) and then converted to year^{-1} for comparability using $K_{\mathrm{yr}^{-1}} = K_{\mathrm{day}^{-1}} \times 365.25$ (Pauly 1984). We report L_∞ in centimetres and t_0 in time units consistent with K. Analyses assumed a locally closed population during the study period (minimal net migration), relatively stable growth and recruitment between November and February, and negligible measurement error relative to the 1-cm bin width (Pauly 1984; Sparre and Venema 1998). To assess robustness, length data were re-binned into 0.5-cm intervals, and estimates of L_∞, K, and t_0 were recalculated. Performed additional checks by excluding the first and last sampling events to evaluate potential boundary effects. Results from these sensitivity tests are presented together with the parameter estimates.

RESULTS AND DISCUSSION

Catch composition and sample overview

A total of 219 *Pomadasys auritus* species were obtained from 16 fishing operations using bottom longlines in the Tarakan coastal waters between November 2022 and February 2023. The catch of fish for fishermen was dominated by demersal fish, with *P. auritus* as the main species, followed by red snapper (*Lutjanus argentimaculatus*), black snapper (*Macolor niger*), whitefin threadfin (*Polynemus melanochir*), and croaker fish (*Otolithes ruber*). Morphological observations included body and head shape, mouth position, fin arrangement, operculum structure, and body colour patterns. Diagnostic characteristics observed included a relatively large head, an elongated and hardened operculum extending beyond the base of the pectoral fins, a small terminal mouth, silver-gold body colouration, a black-spotted interspinosus membrane of the dorsal fin, a dark silver dorsum, and a golden-white ventrum. These characteristics confirm that the analysed specimen is *P. auritus* (Figure 1 and Figure 2). These characteristics align with the morphological descriptions of *P. auritus* in the literature, providing a strong basis for identification.

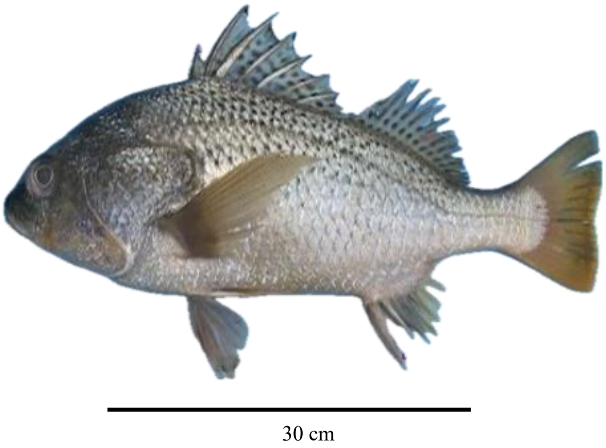

Figure 1. *Pomadasys auritus* sample from Tarakan water, North Kalimantan, Indonesia

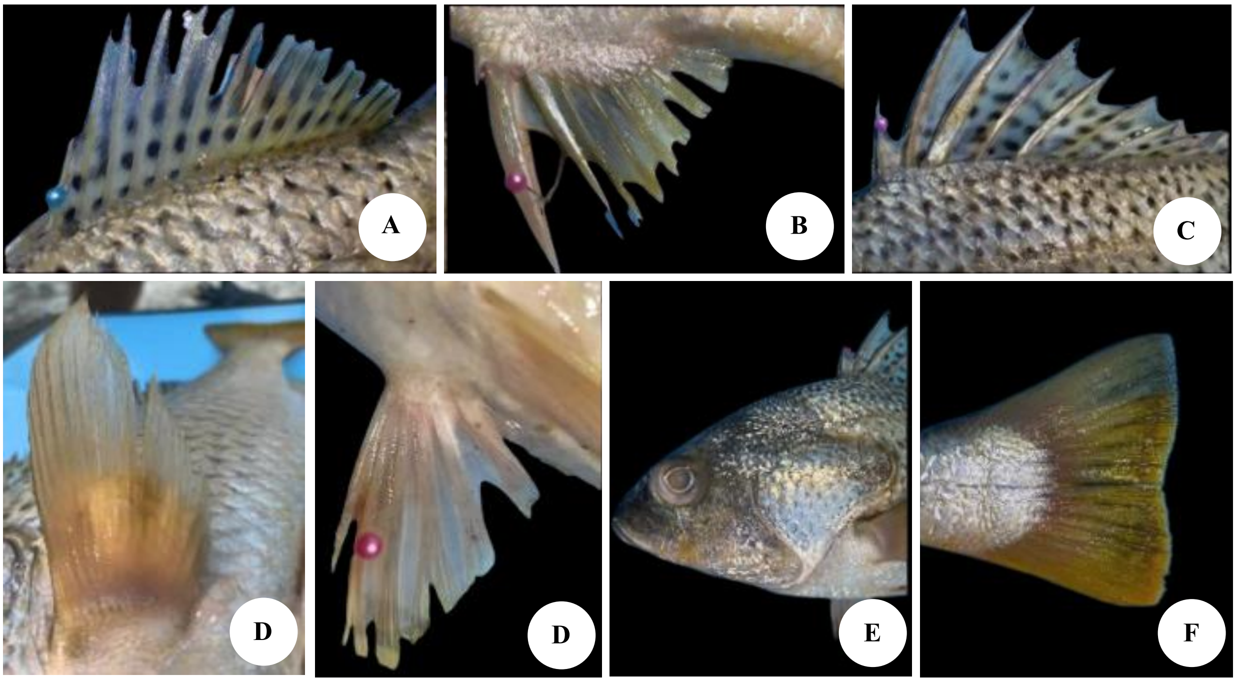

Figure 2. Body parts of *Pomadasys auritus*. A. Second dorsal fin, B. Anal fin, C. First dorsal fin, D. Pectoral fin, E. Ventral fin, F. Operculum, and G. Caudal fin

Growth pattern and Gulland-Holt analysis

A total of 219 individuals of *P. auritus* were analyzed to describe diagnostic morphometric traits from bottom-longline catches in Tarakan waters. The morphometric measurements showed a relatively narrow size range, reflecting the selectivity of bottom-longline gear targeting medium-sized demersal species. Table 1 summarizes the diagnostic morphological characteristics of *P. auritus*, including total and standard length, fin-ray counts, and meristic features, compared with published ranges for closely related P. auritus species. The observed ranges of total length (18.2-29.7 cm) and standard length (14.7-24.8 cm) were consistent with earlier findings by Hata et al. (2015) and Basuonie et al. (2020), confirming that the specimens collected represent adult individuals commonly landed in coastal demersal fisheries of North Kalimantan. The agreement of these morphometric ranges strengthens the validity of the data used in growth modelling, as the fish sizes obtained reflect the adult population structure commonly analysed in length distribution-based growth studies.

All 219 specimens were measured for total length and body weight, and then analyzed for length frequency distribution, length-weight regression, and growth modelling. The mode class shift approach yielded the regression equation $y = -0.0194x+2.1248$, with a coefficient of determination (R^2) of 0.718 and the correlation (r) value is 0.857 (Figure 3). As shown in Figure 3, the Gulland and Holt (1959) plot summarizes mean growth increments by 1-cm length class; hence, the plot displays only aggregated class means rather than individual data points. This length-based approach remains a reliable and widely used technique for tropical demersal fishes, including *P. auritus* species. Recent work by Nader et al. (2024) demonstrated the effectiveness of the Gulland and Holt (1959) model in assessing growth and fishing vulnerability of *Pomadasys stridens* along the Syrian coast. Similarly, Eid and Nashaat (2025) reported consistent results for *P. stridens* populations in Lake Temsah, highlighting the robustness of the von Bertalanffy growth framework for evaluating exploitation dynamics in regional fisheries. High R^2 and r values indicate that the relationship between height gain and height class is consistent. It supports the feasibility of using slope and intercept values as a basis for estimating growth parameters.

Von Bertalanffy growth model (VBGF)

The growth analysis of *P. auritus* provided the foundation for estimating the von Bertalanffy growth model parameters, using the intercept (a) and slope (b) values derived from the Gulland and Holt (1959) plot. The analysis yielded the following parameters: asymptotic length ($L\infty$) = 109.53 cm, growth coefficient (K) = 0.0194 day^{-1}, and theoretical age at zero length (t_0) = -0.823 days. The growth equation obtained is: Lt = 109.526 {1 - e^[-0.0194 (t + 0.823)]}. These results indicate that growth is rapid during the first 270 days (~9 months), then slows down until it reaches its maximum length at approximately 1,330 days (~3.6 years). This trend aligns with the biological energy allocation principle, where growth decelerates as energy shifts from somatic development to reproduction and maintenance processes. Similar growth trajectories have been reported for *P. stridens* in the Eastern Mediterranean (Nader et al. 2024) and Lake Temsah, Egypt (Eid and Nashaat 2025), confirming the consistency of the von Bertalanffy growth framework for demersal species in tropical and subtropical waters (Figure 4).

Interpretation of growth dynamics

Although the L_∞ value appears large compared to the observed maximum size, it remains within the biologically achievable range, as L_∞ is theoretical and not always achieved in nature. Furthermore, the low K value reflects the slow growth pattern typical of relatively long-lived benthic fish. The biological validity of these parameters is strengthened by comparing the L_∞ and K values with the results of previous studies on the genus *Pomadasys*, which have shown similar growth patterns. Additional sensitivity analyses (reclassification of length classes, boundary effect filtering, and parameter reestimation) revealed minimal parameter changes. It confirmed that the presented growth model is stable and reliable under various analytical scenarios.

Table 1. Diagnostic morphological traits of *Pomadasys auritus* from bottom longline catches in Tarakan waters (measured all morphometric and meristic traits on n = 219 individuals)

Character (unit)	Mean±SD (this study)	Range (this study)	Diagnostic range in literature (*Pomadasys* spp.)	Reference(s)
Total length (TL, cm)	23.4±2.8	18.2-29.7	8-30+ (species-dependent)	Hata et al. 2015; Basuonie et al. 2020
Standard length (SL, cm)	19.1±2.3	14.7-24.8	7-25+	Basuonie et al. 2020; Sangeetha et al. 2023
TL/SL ratio	1.22±0.04	1.18-1.29	~1.2-1.3	Hata et al. 2015
Head length (% SL)	28.7±2.1	25.0-33.5	~26-34	Basuonie et al. 2020
Body depth (% SL)	36.5±2.8	31.2-41.0	~34-42	Basuonie et al. 2020; Sangeetha et al. 2023
Dorsal fin formula	XI-XII, 13-15	-	XI-XII, 13-15	Hata et al. 2015; Basuonie et al. 2020
Anal fin formula	III, 7-9	-	III, 7-9	Basuonie et al. 2020
Pectoral fin rays	15-17	-	15-17	Basuonie et al. 2020
Lateral line scales	47-57	-	47-57 (species-dependent)	Hata et al. 2015; Basuonie et al. 2020
Gill rakers (first arch)	8-11	-	8-11	Basuonie et al. 2020

Note: These sources establish the expected meristic ranges (e.g., dorsal fins XI-XII, 13-15, anal fin III, 7-9, pectoral fins 15-17; lateral line scales ~47-57), which were used to examine our Tarakan specimens

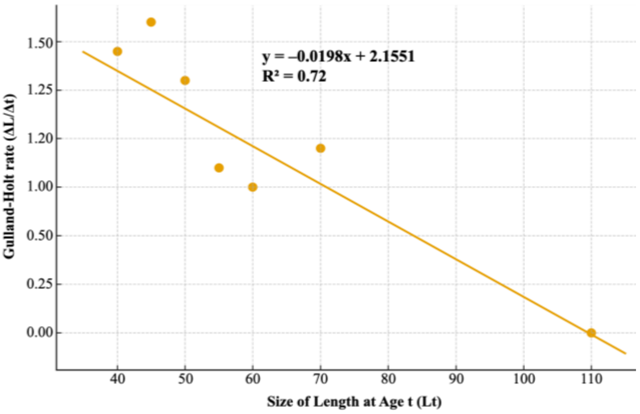

Figure 3. Gulland-Holt plot of growth rate (ΔL/Δt) versus mean length (Lt) for *Pomadasys auritus* from bottom-longline catches in Tarakan. Points represent 1-cm length classes. The dashed line shows the fitted regression (y = -0.0198x + 2.1551; R² = 0.72) used to derive von Bertalanffy growth parameters

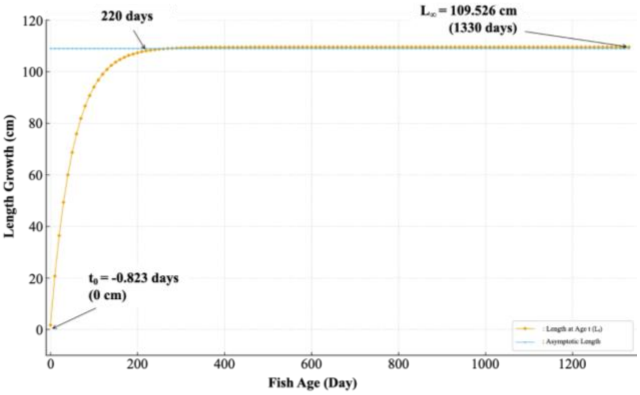

Figure 4. Von Bertalanffy growth model of *Pomadasys auritus* constructed based on length-frequency distribution analysis. The model illustrates the estimated growth trajectory, including asymptotic length (L_∞), growth coefficient (K), and theoretical age at zero length (t_0) derived from population data

Discussion

Length-age relationship and growth trends

Based on sample data of *P. auritus* obtained from this analysis, it became the basis for creating a von Bertalanffy growth model using data on intercept (a) and slope (b) coefficient values. The age structure graph shows a linear relationship between length and age, shifting to the right and decreasing. It indicates the growth rate graph for the sample population of *P. auritus* (Figure 3) caught with a longline has a relationship between with a negative slope. It means that as length increases at a certain age, the growth rate decreases. Salim et al. (2023a, 2023b) found that the regression curve slopes downward to the right, which indicates that the X-axis represents fish length at a given age, while the Y-axis reflects the growth rate of fish, and decreases as body length increases. The regression followed by Salim et al. (2022), added that growth reaches maximum length if the growth speed reaches zero (no additional length growth occurs). These local factors emphasise that *P. auritus* fishery management in Tarakan must consider the dynamics of rapidly changing coastal habitats, including fishing pressure, habitat degradation, and seasonal oceanographic fluctuations.

Growth implications for fisheries

However, according to Salim et al. (2023a, 2023b), it is explained that if maximum length growth has reached zero growth speed, growth will lead to a decrease in body weight. Based on the growth parameter values from the von Bertalanffy growth model, a growth simulation is carried out and produces a growth model in graphical form (Figure 3). As the size of the fish increases, a fish growth model is created, which is one component of several fish stock assessment models. Modelling fish growth, or how fish increase in size as they age, is a key component of some fish stock assessment models. Indarjo et al. (2020a, 2020b) said that the value of the growth coefficient (K) in the von Bertalanffy equation is important because it describes the growth rate to maximum size and can be used to compare growth rates in the same species from different locations or different species. Sparre and Venema (1998) stated that the growth coefficient values and asymptotic length values were different due to factors from outside the fish's body, namely the environment in the form of fluctuating water quality conditions and factors from within the body, namely genetic differences in adaptation. From the perspective of fisheries management in Tarakan, these growth parameters are important because they provide an initial picture of the productive capacity of the fish species and its potential vulnerability to overfishing.

Environmental and ecological factors affecting growth

Environmental conditions in the Tarakan coastal waters are likely to play an important role in shaping the growth performance of *P. auritus*. Seasonal fluctuations in temperature, salinity, and dissolved oxygen can influence metabolic rates, feeding activity, and energy allocation to somatic growth. The relatively shallow and semi-enclosed nature of the Tarakan shelf may also promote variations in prey availability and benthic productivity, factors that are known to affect the growth coefficient (K) among demersal fish populations (Pauly 1984; Froese and Pauly 2024). Moreover, fishing pressure and habitat modifications caused by coastal development can indirectly alter growth patterns through density-dependent effects. Hence, one should interpret the observed growth parameters in this study in the context of these environmental dynamics, and future research should integrate concurrent monitoring of key habitat variables to explain spatiotemporal variability in growth better. These local factors emphasise that *P. auritus* fishery management in Tarakan must consider the dynamics of rapidly changing coastal habitats, including fishing pressure, habitat degradation, and seasonal oceanographic fluctuations.

Morphological and taxonomic

The dominance of demersal fish in the bottom longline catches is consistent with findings in various Indonesian waters, where passive fishing gear tends to result in a high proportion of demersal fish (Pribadi et al. 2025). The critical role of *P. auritus* in coastal areas around Indo-Pacific region waters has also been confirmed, as exemplified by *P. argenteus* in Okinawa, which holds both ecological and economic significance (Uehara et al. 2025). The morphological identification shown in Figure 2, which particularly includes the elongated operculum and small terminal mouth, was consistent with the taxonomic description of the Haemulidae family (Vidthayanon 1999; Hata et al. 2015). However, recent molecular studies on *P. auritus* from Wu et al. (2024) explain the importance of genetic validation to reinforce morphological identification, especially in genera with high interspecific similarity. The consistency of these morphological characteristics supports the proposition that the *P. auritus* population found in Tarakan is an important component of the local demersal community structure. Identification validation is therefore crucial to determine the appropriate population unit for management.

Analysis of growth parameters

The regression equation obtained (Figure 3) shows a very strong model fit ($R^2 = 0.718$; $r = 0.857$), with more than 70% of the variation in growth explained by the model. According to Sugiyono (2015), the correlation coefficient value ranges between 0.8-1.0, indicating a very strong relationship. The estimated asymptotic length ($L\infty = 109.53$ cm) indicates the capacity of *P. auritus* to reach large body sizes, which is a common characteristic of long-lived demersal fish with slow growth rates. This finding is consistent with the growth patterns of red snapper (*Lutjanus malabaricus*) in the Timor Sea ($L\infty = 99.4$ cm; $K = 0.51$ year^{-1}; Herwaty et al. 2023) and *Megalaspis cordyla*) in the Java Sea, which shows isometric growth with a high coefficient of determination ($R^2 > 0.96$ and $r > 0.98$ (Oktaviani et al. 2020). A high L_∞ value indicates that large adult fish still exist in the Tarakan population. However, it also highlights the population's vulnerability to fishing for large fish, which play a crucial role in reproduction.

Biological interpretation of VBGF pattern

The VBGF curve in Figure 4 exhibits a characteristic growth pattern: accelerated length growth in the early phase (0-270 days), followed by a slowdown until it approaches $L\infty$ at ~1,330 days of age. Studies on other reef fishes show similar trends, such as in the Sulawesi Sea, where *Variola albimarginata* and *Variola louti* exhibited asymptotic lengths ($L\infty$) of 54.40-54.90 cm and growth coefficients (K) of 0.54-0.55, indicating that growth stabilises as fish approach older ages (Achmad et al. 2024). However, exploitation rates exceeded sustainable levels, reflecting the trade-offs between growth and mortality in heavily fished stocks (Haser et al. 2023). In contrast, short-lived species such as the mitre squid (*Uroteuthis chinensis*) in Belitung waters reached their maximum growth (Liu et al. 2024) in only about 175 days, illustrating that growth parameters differ markedly between fish and cephalopods (Kurniawan et al. 2025). These findings confirm that the growth of *P. auritus* in Tarakan is strongly influenced by local ecological conditions. Improving the quality of the demersal habitat (for example, by protecting nursery areas and reducing damage to the waterbed) will therefore directly contribute to improved long-term population growth and productivity.

Fish growth parameters were estimated using the von Bertalanffy growth model, a widely applied framework for describing growth dynamics in teleost fishes. This model provides key parameters such as the asymptotic length ($L\infty$), growth coefficient (K), and theoretical age at zero length (t_0), which collectively characterize species-specific growth performance (Rahman et al. 2024). These growth parameters are the estimated maximum length that can be achieved ($L\infty$), the value of the average growth rate or growth coefficient (K) and the estimated age at the null theoretical length (t_0) (Kronbak et al. 2007; Mulfizar et al. 2012; Firdaus et al. 2017; Salim et al. 2023a, 2023b). These growth parameter values help analyse the relationship between length and age, as well as the productivity of fish resource stocks and fisheries management related to selectivity (Kronbak et al. 2007; Mulfizar et al. 2012). The growth coefficient parameter plays an important role in the von Bertalanffy model (Kronbak et al. 2007). In growth analysis, the assumption that the growth coefficient b is constant can only describe fish growth dynamics in a constant environment. Suppose the growth coefficient (b) is replaced with a time-varying function (t). In that case, it provides additional biological realism of the von Bertalanffy model in populations, which allows the description of fish growth rates with time variation (Kronbak et al. 2007). It is of paramount importance that this parameter be applied in the context of Tarakan, as it can serve as a basis for determining the minimum catch size, evaluating exploitation rates, and predicting the Maximum Sustainable Yield (MSY) to maintain the sustainability of *P. auritus* stocks. This pattern is consistent with the concept of autocatalytic growth (Effendie 2002; Firdaus et al. 2013). After reaching maximum size, metabolic energy is diverted to body weight gain, predator avoidance (Firdaus et al. 2020), gonad development (Firdaus et al. 2021b), cell repair, and body maintenance (Salim et al. 2020c; 2023a). This change in energy allocation reflects a biological trade-off common in long-lived demersal fish, where survival and reproduction are prioritized over continued somatic growth. Understanding this energy distribution is important for fisheries management in Tarakan, as large specimens contribute most to reproduction. Intensive fishing in this size class can therefore hinder the population's ability to recover.

A comparison with previous research in Tarakan by Firdaus et al. (2021a) shows spatial and temporal variations. The study reported lower growth parameters ($L\infty = 71.3$ cm; $K = 0.0127$ day^{-1}; $t_0 = -1.067$), which differences may have been influenced by environmental conditions, feed availability, fishing intensity, and sampling methods. The graph of the von Bertalanffy growth model with constant coefficients shows that when the *P. auritus* fish samples were 0 to 270 days old, they experienced a rapid growth process until they reached a length of around 108,953 cm. When *P. auritus* were 270 to 1330 days old, the fish experienced slowed growth, or the increase/change in length slowed down. During this period, physiological development and internal maintenance processes occur in fish. The *P. auritus* is thought to reach a maximum length of 109.526 cm at the age of 1330 days. The process of growth in length of the *P. auritus* is slowing down because the energy originating from the fish's metabolism is only used for fish movement, repairing damaged fish cells and the development of the fish's physiological functions (reproduction and sensory). It is in accordance with the statement by Effendie (2002) and Firdaus et al. (2013), who explain that the concept of growth exhibits autocatalytic properties, whereby growth initially proceeds slowly, then rapidly, and subsequently slows until it reaches a constant length. Salim et al. (2023a, 2023b) added that when growth in length has reached its maximum, growth is used towards weight and size and avoiding predators (Firdaus et al. 2020), towards gonad development (Firdaus et al. 2021b), repair of damaged cells and maintenance of the body (Salim et al. 2020c). Differences in growth parameter values between studies confirm that *P. auritus* stocks in Tarakan are dynamic and highly responsive to fishing conditions and the local environment. Therefore, long-term monitoring is necessary to make more accurate management recommendations.

Similar to this, Tjahjo et al. (2023) demonstrated that seasonal fluctuations in water quality and nutrient dynamics significantly influence the variability in growth and productivity of aquatic biota. Their study in East Aceh waters revealed that parameters such as dissolved oxygen, turbidity, and nutrient availability (particularly N and P) fluctuate significantly across seasons, directly influencing primary productivity and, consequently, the carrying capacity of local ecosystems. Such environmental instability highlights that differences in growth parameters reported across studies may not solely reflect the biological characteristics of the species, but also the surrounding habitat conditions and anthropogenic pressures (e.g., pollution and fishing intensity). This variability emphasizes the need for multi-year and multi-location monitoring to obtain more accurate estimates, as well as to form the basis for developing adaptive stock management strategies (Tjahjo et al. 2023). It suggests that *P. auritus* management strategies in Tarakan should be adaptive and based on regularly updated environmental data, particularly during seasons of extreme oceanographic stress.

In addition, several field-based studies in Tarakan waters have documented the ecological characteristics and fishery practices that influence demersal fish productivity and community structure. The demersal assemblage in this area comprises more than 80 species across 45 families, dominated by Leiognathidae, Sciaenidae, and Haemulidae, with moderate species diversity (H' = 1.7-2.5) and relatively even distribution across muddy-substrate fishing grounds (Suprapto 2014). Fishing operations around Tarakan are conducted mainly with bottom longlines and small trawls that target snappers, groupers, and grunts (*Pomadasys* spp.), typically from vessels of 4-6 GT operating at 10-40 m depth (Rahmat and Yahya 2019). Comparatively, studies on *P. argenteus* in Okinawa Bay demonstrate that this genus depends heavily on nearshore nursery habitats throughout its life history, underscoring its vulnerability to habitat alteration and intensive coastal fishing (Uehara et al. 2025). Together, these findings underscore the ecological and socioeconomic significance of *P. auritus* within the regional demersal fishery, highlighting the need for area-specific stock assessments and adaptive management strategies in North Kalimantan. It means that management of *P. auritus* in Tarakan should prioritise protection of the breeding habitat, regulation of fishing effort (effort control) and the application of minimum catch sizes to avoid a catch consisting mainly of immature gonads.

Beyond Tarakan, *P. auritus* has been recorded in the northern Borneo sector of the South China Sea (Sabah-Sarawak), indicating a continuous biogeographic footprint across Borneo's coastal shelf (Vidthayanon 1999). Within Indonesia, the species is also documented from the eastern coast of Sumatra (Musi basin), supporting its occurrence in multiple Indonesian coastal provinces (Iqbal et al. 2018). Together with taxonomic syntheses for Haemulidae (Parenti 2019), these records justify treating the Tarakan population within a broader regional context while retaining site-specific interpretation of growth parameters. Given this broad distribution, determining the stock unit for Tarakan is crucial so that management policies are not only locally effective but also reflect stock dynamics in potentially interconnected regions.

Although this study has produced reliable growth parameters for *P. auritus*, it does not yet provide estimates of fishing mortality or exploitation rate, both of which are crucial for evaluating the sustainability of the stock. A quantitative assessment of the mortality components, natural mortality (M), fishing mortality (F), and total mortality (Z), is necessary to determine whether the population is being harvested within ecologically safe limits. Recent global reviews have highlighted that obtaining precise estimates of natural mortality remains one of the most persistent challenges in fisheries biology, since even minor errors in *M* can substantially affect the accuracy of total mortality estimates and, consequently, the assessment of stock status (Campos et al. 2024). Empirical approaches originally proposed by Pauly (1984) have since been refined through the inclusion of environmental and life-history parameters, resulting in more robust mortality estimators for tropical demersal fishes (Campos et al. 2024). This analysis of mortality and exploitation is crucial for Tarakan, given the increasing pressure on the fishing industry. Therefore, a length-based stock assessment is needed in further research.

Furthermore, both regional and global modelling studies underline the importance of spatially explicit exploitation indices (F/F_{msy}) for linking population-level dynamics to broader ecosystem processes (van Denderen et al. 2024). In subsequent analyses, these parameters could be estimated using catch-only assessment frameworks or length-based catch curve models that combine empirical *M.* estimators with mechanistic mortality models to quantify exploitation rates and Maximum Sustainable Yield (MSY). Incorporating such analyses would extend the biological dataset presented here into a more integrated stock-assessment framework, thereby strengthening its relevance for adaptive fisheries management and the sustainable utilisation of demersal fish resources in North Kalimantan. The results of this study provide an important starting point for developing a more comprehensive, evidence-based, and adaptive framework for managing *P. auritus* fish stocks in Tarakan, addressing ecological change and fishing pressure.

In conclusion, this study confirmed the identification of *P. auritus* from bottom longline catches in Tarakan waters based on diagnostic morphological traits, and estimated its growth parameters using the von Bertalanffy growth model ($L\infty = 109.53$ cm; $K = 0.0194$ day^{-1}; $t_0 = -0.823$ days). The results indicate a slow growth pattern with the potential to reach large body sizes, a typical feature of long-lived demersal fishes that increases their vulnerability to overexploitation. The significance of this study lies in presenting the first morphological and growth parameter data for *P. auritus* in Tarakan waters, providing an essential scientific baseline for stock assessment and management of this economically important demersal species. However, this study has limitations because it only used landing data (depending on the fishery), which may not fully capture the natural variation in population structure. Further research should therefore include information on reproductive biology (e.g., sexual maturity and spawning season), feeding ecology, environmental variability, and population genetic analysis to strengthen our understanding of population dynamics. Furthermore, the integration of mortality parameters (M, F, and Z) is essential for a more comprehensive population assessment and to support sustainable management strategies for the *P. auritus* fishery in Tarakan.

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REFERENCES

Achmad DS, Nurdin MS, Tilome AA, Moore AM. 2024. Population dynamics of *Variola albimarginata* Baissac, 1953 and *Variola louti* Fabricius, 1775 (Perciformes: Serranidae) in Sulawesi Sea, Indonesia. Biodiversitas 25 (3): 978-989. DOI: 10.13057/biodiv/d250310.

Ahmad HMA, Yousaf MR, Ahmed B, Kurnianto E, Lestari DA, Mustofa F, Sutopo S, Setiaji A. 2025. Phenotypic characteristics of native chickens in Libya based on morphometric and plumage traits. Biodiversitas 26 (8): 3659-3673. DOI: 10.13057/biodiv/d260801.

Akalın S, Sever TM, İlhan D, Kaya M, Altay B. 2025. Length-weight relationship and diet composition of *Pomadasys stridens* (Forsskål, 1775) from İskenderun Bay (Eastern Mediterranean Sea). Çanakkale Onsekiz Mart Univ J Mar Sci Fish 8 (1): 14-22. DOI: 10.46384/jmsf.1591598.

Al-Hafidz Z, Susilowati I, Waridin W, Maria NSB, Iskandar DD. 2024. Enhancing livelihood resilience: A comprehensive analysis of small-scale fishers. J Sustain Res 6: e240064. DOI: 10.20900/jsr20240064.

Annisa CA, Rahardjo MF, Zahid A, Simanjuntak CPH, Asriansyah A, Aditriawan RM. 2018. Makanan dan kebiasaan makan ikan gerot-gerot *Pomadasys kaakan* (Cuvier, 1830) di Teluk Pabean, Jawa Barat. Jurnal Perikanan Universitas Gadjah Mada 20 (1): 31-40. DOI: 10.22146/jfs.31498. [Indonesian]

Avşar D, Mavruk S, Yeldan H, Manaşirli M. 2021. Population dynamics of an emergent invasive fish, striped piggy, *Pomadasys stridens* (Actinopterygii, Perciformes, Haemulidae) in the Gulf of İskenderun, north-eastern Mediterranean. Acta Ichthyol Piscat 51 (1): 13-21. DOI: 10.3897/aiep.51.e63320.

Basuonie AAA, Sabrah MM, El-Sherbeny ASH, El-Sabbagh MSA. 2020. Analysis of morphometric and meristic characteristics of *Pomadasys stridens* (Forsskål, 1775), family: Haemulidae from the Gulf of Suez, Red Sea, Egypt. Egypt J Aquat Biol Fish 24 (6): 281-294. DOI: 10.21608/ejabf.2020.112083.

Brogan D. 2002. Port Sampling Manual. Secretariat of the Pacific Community, Noumea Cedex, New Caledonia.

Campos CP, Inomata DO, Inomata SO, Bitar S, Freitas CEC. 2024. Natural mortality of fish: A review. Braz J Biol 84 (2): e288214. DOI: 10.1590/1519-6984.288214.

Damora A, Fazilla F, Perdana AW, Rahmah A, Aprilla RM, Salmarika S. 2021. Population dynamics of skipjack tuna (*Katsuwonus pelamis*) in the northern and western waters of Aceh. IOP Conf Ser: Earth Environ Sci 674: 012089. DOI: 10.1088/1755-1315/674/1/012089.

Effendie MI. 2002. Biologi Perikanan. Institut Pustaka Nusantara, Yogyakarta. [Indonesian]

Eid NM, Nashaat M. 2025. Mortality rates, relative yield per recruit and parasitic infestations of Striped piggy (*Pomadasys stridens*) from Lake Temsah, Egypt. Egypt J Aquat Biol Fish 29 (5): 361-380. DOI: 10.21608/ejabf.2025.416415.6454.

Endo C, Watanabe K. 2020. Morphological variation associated with trophic niche expansion within a lake population of a benthic fish. PLoS One 15 (4): e0232114. DOI: 10.1371/journal.pone.0232114.

Firdaus M, Kamelia K. 2011. Kajian fishing gear serta metode pengoperasian rawai (*longline*) di perairan bagian Selatan Pulau Tarakan. Jurnal Borneo Saintek 4 (1): 10-19. [Indonesian]

Firdaus M, Salim G, Cahyadi J, Weliyadi E, Bintoro G. 2020. Model and nature of growth of red snapper fish (*Lutjanus argentimaculatus*, Forsskål, 1775) fishing catch of bottom fish pots in Bunyu Waters, North Kalimantan. AACL Bioflux 13 (3): 1410-1421.

Firdaus M, Salim G, Maradhy E, Abdiani IM, Syahrun S. 2013. Analisis pertumbuhan dan struktur umur ikan nomei (*Harpodon nehereus*) di perairan Juata Kota Tarakan. Jurnal Akuatika 4 (2): 159-173. [Indonesian]

Firdaus M, Soemarno, Bintoro G, Lelono TD. 2017. Growth and age structure of Nomei (*Harpadon nehereus*, Ham. 1822) in Juata Laut waters of Tarakan Island, North Borneo, Indonesian. Intl J Sci Basic Appl Res 31 (2): 208-218.

Firdaus M, Wiharyanto D, Yudianti AN. 2021a. Ukuran pertama matang gonad dan tertangkap ikan Senagin (*Eleutheronema* sp.) dan ikan Arut (*Lutjanus* sp.) di perairan Tarakan. Jurnal Borneo Saintek 4 (2): 84-92. DOI: 10.35334/borneo_saintek.v4i2.2032. [Indonesian]

Firdaus M, Wiharyanto D, Yudianti AN. 2021b. Model pertumbuhan ikan Arut (*Lutjanus* sp.) hasil tangkapan jaring insang (*gillnet*) di perairan Tarakan. J Harpodon Borneo 14 (2): 82-87. DOI: 10.35334/harpodon.v14i2.2024. [Indonesian]

Froese R, Pauly D. 2024. FishBase. World Wide Web Electronic Publication. www.fishbase.org.

Gayanilo FC, Sparre P, Pauly D. 2005. FAO-ICLARM Stock Assessment Tools II (FiSAT II) Revised version, User's Guides. FAO Computerized Information Series (Fisheries), Rome, FAO.

Ghosh P. 2014. Subsistence and Biodiversity Conservation in the Sundarban Biosphere Reserve, West Bengal, India. [Doctoral Dissertation]. University of Kentucky, Lexington, Kentucky, USA. Retrived from https://uknowledge.uky.edu/geography_etds/26.

Greenstreet SPR, Rossberg AG, Fox CJ, Le Quesne WJF, Blasdale T, Boulcott P, Mitchell I, Millar C, Moffat CF. 2012. Demersal fish biodiversity: Species-level indicators and trends-based targets for the Marine Strategy Framework Directive. ICES J Mar Sci 69 (10): 1789-1801. DOI: 10.1093/icesjms/fss148.

Gulland JA, Holt SJ. 1959. Estimation of growth parameters for data and unequal time intervals. J Cons 25: 47-49. DOI: 10.1093/icesjms/25.1.47.

Haser TF, Nurdin MS, Supriyono E, Prihadi TH, Febri SP, Persada AY, Wibowo TH, Sari HPE, Putri KA, Antoni A. 2023. Stock assessment using spawning potential ratio in data poor fisheries for mahseer *Tor tambroides* (Bleeker, 1854) in Aceh Province, Indonesia. Biodiversitas 24 (11): 6039-6047. DOI: 10.13057/biodiv/d241125.

Hata H, Itou M, Motomura H. 2015. First japanese record of the Haemulid fish *Pomadasys kaakan* (Perciformes), from Kagoshima Prefecture, Southern Japan. Species Divers 20: 115-120. DOI: 10.12782/sd.20.2.115.

Herwaty S, Mallawa A, Najamuddin, Zainuddin M. 2023. Age, growth, mortality, and population characteristics of the red snapper (*Lutjanus malabaricus*) in the Timor Sea waters, Indonesia. Biodiversitas 24 (4): 2217-2224. DOI: 10.13057/biodiv/d240434.

Indarjo A, Salim G, Amir F, Supriadi S, Soejarwo PA, Nugraeni CD, Prakoso LY, Ambariyanto A, Firdaus M, Ransangan J. 2020a. Growth characteristics Layur fish *Lepturacanthus savala* in Juata Waters, Tarakan, Indonesia. Ilmu Kelautan: Indones J Mar Sci 25 (3): 127-134. DOI: 10.14710/ik.ijms.25.3.127-134.

Indarjo A, Salim G, Nugraeni CD, Anggoro S, Maryanto TI, Prakoso LY, Pramono B, Azis A, Meiryani M, Ransangan J, Khasani I. 2022. Preliminary study on the domestication of giant freshwater prawn, *Macrobrachium rosenbergii* (De Man, 1879) from North Kalimantan, Indonesia. AACL Bioflux 15 (6): 3121-3130.

Indarjo A, Salim G, Zein M, Susiyanti S, Soejarwo PA, Nugraeni CD, Bija S, Pham YTH. 2020b. Characteristics of Von Bertalanfy growth, allometric, condition index and mortality of *Periophthalmus barbarus* in Mangrove and Probiotics Conservation Area (KKMB), Tarakan, North Kalimantan. Ilmu Kelautan: Indones J Mar Sci 25 (1): 31-38. DOI: 10.14710/ik.ijms.25.1.31-38.

Iqbal M, Indra Y, Arum S, Setiawan D. 2018. Ikan-Ikan di Sungai Musi dan Pesisir Timur Sumatera Selatan. Yayasan Kelompok Pengamat Burung Spirit of South Sumatra, Palembang. [Indonesian]

Jabarsyah A, Rahmawani D, Taqwa A, Simanjuntak RF. 2022. Ichtyofauna in Kayan watershield Bulungan Regency, North Kalimantan. IOP Conf Ser: Earth Environ Sci 1083: 012004. DOI: 10.1088/1755-1315/1083/1/012004.

Kronbak LG, Andersen SE, Boom JT, Eliasen S, Frost H, Hoff A, Jørgensen O, Krog C, Mathiesen C, Nielsen JR, Munch Petersen S, Sverdrup-Jensen S, Vestergaard N. 2007. Implementering af mere selektive og skånsomme fiskerier - Konsekvenser for ressource, fiskere og samfund. IME Report 11/07. Department of Environmental and Business Economics (IME). University of Southern Denmark, Denmark. [Danish]

Kurniawan R, Tirtadanu T, Puspasari R, Putri MRA, Amri K, Rahman A, Sugianti Y, Mujiyanto M, Lestari P, Wagiyo K. 2025. Exploring the population ecological characteristics and the stock status of mitre squid (*Uroteuthis chinensis* Gray, 1849) in Belitung waters, Indonesia. Braz J Biol 85: e292066. DOI: 10.1590/1519-6984.292066.

Liu D, Zhang C, Guo J, Wang H, Pang Y, Tian Y. 2024. Age and growth of Mitre squid (*Uroteuthis chinensis*) in the Northwestern South China Sea based on statolith microstructure analysis. Diversity 16 (7): 395. DOI: 10.3390/d16070395.

MacNeil L, Madiraca F, Otto S, Scotti M. 2025. Spatial change of dominant Baltic Sea demersal fish across two decades. Ecol Evol 15 (4): e71309. DOI: 10.1002/ece3.71309.

Mak YKY, Tao LSR, Ho VCM, Dudgeon D, Cheung WWL, Leung KMY. 2021. Initial recovery of demersal fish communities in coastal waters of Hong Kong, South China, following a trawl ban. Rev Fish Biol Fish 31: 989-1007. DOI: 10.1007/s11160-021-09685-5.

Mildenberger TK, Taylor MH, Wolff M. 2017. TropFishR: An R package for fisheries analysis with length-frequency data. Methods Ecol Evol 8 (11): 1520-1527. DOI: 10.1111/2041-210X.12791.

Mulfizar, Muchlisin ZA, Dewiyanti I. 2012. Hubungan panjang berat dan faktor kondisi tiga jenis ikan yang tertangkap di Perairan Kuala Gigieng, Aceh Besar, Provinsi Aceh. Depik 1 (1): 1-9. DOI: 10.13170/depik.1.1.21. [Indonesian]

Nader IH, Nour AB, Hamam A, Jullanar S. 2024. Assessment of population growth and fishing vulnerability of *Pomadasys stridens* along the Syrian Coast (Eastern Mediterranean Sea). Intl J Oceanogr Aquac 8 (3): 000333. DOI: 10.23880/ijoac-16000333.

Oktaviani D, Priyanto E, Nugroho D. 2020. Length-weight, maturity, and condition factor of torpedo scads (*Megalaspis cordyla* Linnaeus, 1758) in the Java Sea, Indonesia. Biodiversitas 21 (4): 1527-1534. DOI: 10.13057/biodiv/d210433.

Olopade OA, Dienye HE, Okonkwo CC. 2020. Biometric indices and condition factors of *Pomadasys jubelini* (Cuvier, 1830) from Obuama Creek, Nigeria. Ilmu Kelautan: Indones J Mar Sci 25 (2): 45-52. DOI: 10.14710/ik.ijms.25.2.45-52.

Osman HM, Saber MA, El Ganainy AA. 2019. Population structure of the striped piggy Pomadasys stridens in the Gulf of Suez. Egypt J Aquat Res 45 (1): 53-58. DOI: 10.1016/j.ejar.2019.02.002.

Parenti P. 2019. An annotated checklist of the fishes of the family Haemulidae (Teleostei: Perciformes). Iran J Ichthyol 6 (3): 150-196. DOI: 10.22034/iji.v6i3.408.

Pauly D. 1984. Fish Population Dynamics in Tropical Waters a Manual for Use with Programmable Calculators. International Center for Living Aquatic Resources Management, Studies and Reviews, Manila.

Perdana I, Salim G, Weliyadi E. 2016. Perbandingan rasio kelamin, mortalitas dan pertumbuhan nomei (*Harpadon nehereus*) yang berasal dari hasil penangkapan nelayan Juata Kota Tarakan. J Harpodon Borneo 9: 133-142. DOI: 10.35334/harpodon.v9i2.170. [Indonesian]

Pribadi TDK, Yusfiandayani R, Simbolon D, Patanda M, Caesario R, Sayidina EJ, Violita SR. 2025. A comparison of diversity and catch composition of mini trawl (*arad*) and lift net (*bagan*) in Cilincing, Jakarta Bay, Indonesia. Biodiversitas 26 (1): 265-277. DOI: 10.13057/biodiv/d260127.

Rahman O, Laboni TA, Khatun MS, Rahman MA, Islam MA, Rahman MM, Parvin MF, Abedin MJ, Hossain MY. 2024. Estimating the growth parameters, exploitation rate, biomass and maximum sustainable yield of long whisker catfish *Mystus gulio* (Hamilton, 1822) in the coastal waters from southwestern Bangladesh. Heliyon 10 (8): e29788. DOI: 10.1016/j.heliyon.2024.e29788.

Rahmat E, Yahya MF. 2019. Teknik penangkapan ikan dengan rawai dasar dan informasi komposisi jenis hasil tangkapan oleh nelayan Tarakan (WPPNRI 716 - Laut Sulawesi). Buletin Teknik Litkayasa 17 (2): 99-103. DOI: 10.15578/btl.17.2.2019.99-103. [Indonesian]

Salim G, Azis A, Prasetia AM, Indarjo A, Rukisah R, Meiryani M, Lailaturrif'ah, Wulandari E, Jalil A, Fauzi MA, Toha T, Anggoro S, Ransangan J, Mujiyanto M. 2023b. Growth, mortality, and reproductive model of Bombay duck (*Harpodon nehereus*, Hamilton 1822) in Juata Laut waters, North Kalimantan. AACL Bioflux 16 (4): 1864-1877.

Salim G, Azis A, Prasetia AM, Meiryani M, Rukisah R, Indarjo A, Fatwa AT, Lailaturrif'ah, Wulandari E, Jalil A, Fauzi MA, Toha T. 2023a. Growth pattern and the condition index of Nomei fish *Harpodon nehereus* captured with mini-trawl in Tarakan Waters. IOP Conf Ser: Earth Environ Sci 1260: 012008. DOI: 10.1088/1755-1315/1260/1/012008.

Salim G, Handayani KR, Anggoro S, Indarjo A, Syakti AD, Ibrahim AJ, Ransangan J, Prakoso LY. 2020b. Morphometric analysis of *Harpodon nehereus*, *Harpiosquilla raphidea*, and *Scylla serrata* in the coastal waters of Tarakan, North Kalimantan, Indonesia. Biodiversitas 21 (10): 4829-4838. DOI: 10.13057/biodiv/d211049.

Salim G, Handayani KR, Indarjo A, Ransangan J, Atieqah N. 2020a. Growth, mortality and exploitation rate of *Pampus argenteus, Parastromateus niger* and *Scomberomorus commerson* in Sebatik Waters, Indonesia. Biodiversitas 21 (11): 5363-5372. DOI: 10.13057/biodiv/d211142.

Salim G, Handayani KR, Indarjo A, Ransangan J, Rizky R, Prakoso LY, Pham YTH. 2021. Characteristics of population growth and mortality of windu shrimp (*Penaeus monodon*) in the Juata Water of Tarakan City, Indonesia. Jurnal Ilmiah Perikanan dan Kelautan 13 (1): 124-130. DOI: 10.20473/jipk.v13i1.21475.

Salim G, Hendrikus H, Indarjo A, Prakoso LY, Haryono MG, Irawan A, Ransangan J. 2022. Characteristics of model growth and mortality of white shrimp (*Penaeus merguiensis* de Man 1888) in the estuary of

Bengara, Regency Bulungan. IOP Conf Ser: Earth Environ Sci 1083: 012083. DOI: 10.1088/1755-1315/1083/1/012083.

Salim G, Indarjo A, Mujiyanto M, Sugianti Y, Anggoro S, Ransangan J, Nawir D, Meiryani M, Hartinah S, Nurjanah N, Jose AES, Dewi R, Balqis Z, Arief MCW, Putri MRA, Rahman A. 2024. Growth and mortality model of Chacunda gizzard shad *Anodontostoma chacunda* (Bleeker, 1852) in Tarakan waters, North Kalimantan, Indonesia. Biodiversitas 25 (2): 770-780. DOI: 10.13057/biodiv/d250237.

Salim G, Indarjo A, Zein M, Prakoso LY, Suhirwan, Daengs GSA, Rukisah R. 2020c. The allometric growth and condition index comparison of white shrimp (*Litopenaeus vannamei*) from fishpond and Juata Laut Waters, Tarakan (Indonesia). IOP Conf Ser: Earth Environ Sci 564: 012009. DOI: 10.1088/1755-1315/564/1/012009.

Sangeetha AT, Nair RJ, Vishnupriya KM. 2023. Notes on the morphometry and biology of the Saddle grunt, *Pomadasys maculatus* (Bloch, 1793) recorded from the Southeast Arabian Sea. J Mar Biol Assoc India. 65 (2): 109-115. DOI: doi:10.6024/jmbai.2023.65.2.2367-17.

Sparre P, Venema SC. 1998. Introduction to Tropical Fish Stock Assessment, Part I. Manual. FAO Fisheries Technical Paper, FAO, Rome.

Sugiyono. 2015. Metode Penelitian Kombinasi (Mix Methods). Alfabeta, Bandung. [Indonesian]

Suprapto S. 2014. Indeks keanekaragaman jenis ikan demersal di Perairan Tarakan. Bawal 6 (1): 47-53. DOI: 10.15578/bawal.6.1.2014.47-53. [Indonesian]

Syam AR, Mujiyanto M, Rahman A et al. 2023. Eco-environmental assessment in the Sembilan Archipelago, Indonesia: Its relation to the abundance of humphead wrasse and coral reef fish composition. Fish Aquat Sci 26 (12): 738-751. DOI: 10.47853/fas.2023.e66.

Tjahjo DWH, Wiadnyana NN, Purnamaningtyas SE, Arifin T, Yulius Y, Purbani D, Syam AR, Mujiyanto, Wisha UJ. 2023. Assessment of water quality status, nutrients, and phytoplankton communities in the coastal zone of East Aceh Regency, Indonesia. J Ecol Eng 24 (9): 112-129. DOI: 10.12911/22998993/168614.

Uehara M, Chimura Y, Ohta I, Ebisawa A, Miyaoka Y, Tachihara K. 2025. Pelagic early development of the silver grunt *Pomadasys argenteus* in Nakagusuku Bay, Okinawa, Japan, with notes on its occurrence and spawning patterns. Discov Anim 2: 38. DOI: 10.1007/s44338-025-00091-w.

van Denderen PD, Jacobsen N, Andersen KH, Blanchard JL, Novaglio C, Stock CA, Petrik CM. 2024. Estimating fishing exploitation rates to simulate global catches and biomass changes of pelagic and demersal fish. Earth's Future 12: e2024ef004604. DOI: 10.1029/2024ef004604.

Vidthayanon C. 1999. Species composition and diversity of fishes in the South China Sea, Area II: Sarawak, Sabah and Brunei Darussalam waters. In: Proceedings of the Second Technical Seminar on Marine Fishery Resources Survey in the South China Sea, Area II: West Coast of Sabah, Sarawak and Brunei Darussalam, 14-15 December 1998, Kuala Lumpur, Malaysia. Samut Prakan, Thailand: Training Department, Southeast Asian Fisheries Development Center. Retrived from http://hdl.handle.net/20.500.12067/821.

Wu T, Sun C-H, Lao Y-L, Zhang Q. 2024. Genetic diversity and population structure of threeline grunt *Parapristipoma trilineatum* (Perciformes: Haemulidae) in China and Japan based on mtDNA control region. Glob Ecol Conserv 53: e03038. DOI: 10.1016/j.gecco.2024.e03038.