JoMS | Journal of Marine Studies

Research article

OPEN ACCESS

Biometric characteristics of eel *Anguilla bicolor* in Krueng Sawang River, North Aceh, Indonesia

Mulyadi Mulyadi [1], *, Zulfikar Zulfikar [2], Munawar Khalil [2]

[1] Department of Aquaculture, Faculty of Agriculture, Universitas Malikussaleh. Reuleut Main Campus, 24355 North Aceh, Aceh, Indonesia.

[2] Department of Marine Science, Faculty of Agriculture, Universitas Malikussaleh. Reuleut Main Campus, 24355 North Aceh, Aceh, Indonesia.

Abstract

Eels are a valuable economic resource in both local and international markets due to their high nutritional content, particularly their rich vitamin and micronutrient profile. However, their populations face increasing threats from overfishing and habitat degradation, necessitating a deeper understanding of their distribution, growth patterns, and ecological characteristics. This study aimed to identify eel (*Anguilla bicolor*) species inhabiting the Krueng Sawang River, analyze their length-weight relationships, and assess biometric variations among different sampling locations. Fieldwork was conducted in April and May 2018 across three sampling stations in North Aceh District: Tanoh Anoe (Station 1), Gle Dagang (Station 2), and Babah Krueng (Station 3). A total of 100 eels were collected, with individuals from Station 1 averaging 50.17 cm in length and 237.78 g in weight, those from Station 2 averaging 31.96 cm in length and 135.93 g, and specimens from Station 3 averaging 35.18 cm in length and 148.21 g. Morphological analysis confirmed that all collected specimens belonged to *A. bicolor*, indicating a homogeneous population within the river system. The length-weight relationship analysis revealed a negative allometric growth pattern, suggesting that increases in length outpace weight gain. These findings provide valuable insights into the population dynamics of *A. bicolor* in North Aceh, offering essential baseline data for future conservation efforts and the development of sustainable fisheries management strategies.

Keywords: Catadromous fish, population dynamics, morphometric analysis, length-weight relationship, water quality assessment

Citation:
Mulyadi, M., Zulfikar, Z., & Khalil, M. (2025). Biometric characteristics of eel *Anguilla bicolor* in Krueng Sawang River, North Aceh, Indonesia. *Journal of Marine Studies, 2*(1), 2104. https://doi.org/10.29103/joms.v2i1.21108.

Received: February 25, 2024
Revised: March 26, 2025
Accepted: March 27, 2025
Published: March 29, 2025

Subject areas:
Marine biology

***Correspondence**:
Mulyadi Mulyadi
e-mail: mulyadi@mhs.unimal.ac.id

Introduction

The eel species *A. bicolor* is of considerable economic and ecological importance, primarily due to its high market value and rich nutritional profile (Karakoltsidis & Constantinides, 2009). This species is recognized for its substantial content of essential vitamins and micronutrients, making it a popular dietary choice both locally and globally (Muchlisin et al., 2017; Nafsiyah et al., 2018). Eel consumption is often linked to various health benefits, particularly its reputed vitality-enhancing properties, which have contributed to growing demand in global culinary markets (Hutchinson et al., 2024; Wibowo et al., 2021). The unique flavor profile and versatility of *A. bicolor* in various culinary applications further amplify its desirability among consumers, thus intensifying market pressures on wild populations (Wibowo et al., 2021).

Despite its economic significance, the sustainability of natural eel populations is increasingly threatened by a combination of factors, including inherently slow growth rates and the widespread issue of overexploitation (Arai et al., 2011; Wirth & Bernatchez, 2003). As a catadromous species, *A. bicolor* exhibits complex migratory behavior, transitioning from freshwater habitats to marine environments for spawning purposes (Arai & Chino, 2019). This cyclical migration is crucial for reproductive success and long-term population viability, as it facilitates the return of adult eels to their natal spawning grounds (Sudo et al., 2024). The ecological dynamics of these migratory patterns are essential for maintaining population stability and resilience in the face of anthropogenic pressures (Muchlisin et al., 2017).

The natural habitat of *A. bicolor* on the Krueng Sawang River of North Aceh, Indonesia, comprises a river system approximately 10 m in width and is characterized by several tributaries that play a vital role in supporting local agricultural practices, irrigation systems, and fisheries activities. Although this environment has the potential to sustain eel populations, fishing practices in this area remain predominantly focused on subsistence consumption. This limitation is largely attributable to the intricate reproductive cycle of *A. bicolor*, which requires advanced hatchery technologies for successful artificial propagation. Consequently, the growing market demand for eels continues to rely heavily on wild-caught specimens, exacerbating concerns about the sustainability of eel populations and the risk of resource depletion due to unregulated fishing practices (Muchlisin et al., 2017).

The Krueng Sawang River serves as a critical habitat for *A. bicolor*; however, the lack of comprehensive scientific data on its biometric characteristics and population dynamics underscores the urgent need for further research (Arai & Abdul Kadir, 2017). Previous studies have highlighted the genetic connectivity and life history strategies of *A. bicolor* in various regions (Minegishi et al., 2011; Tsukamoto et al., 2011), but there remains a significant gap in understanding the specific biometric parameters and ecological interactions within the Krueng Sawang River ecosystem. The primary objective of this study is to perform a thorough assessment of the biometric aspects of *A. bicolor* within this ecosystem. This investigation will encompass the identification of eel species present in the area, the analysis of length-weight relationships, and an examination of the biometric characteristics of the eel population (Wibowo et al., 2021). Additionally, the study aims to explore the correlation between water quality parameters and eel growth patterns, thus elucidating the environmental factors that may influence the health and viability of this species (Muchlisin et al., 2017).

The anticipated findings of this research are expected to produce significant contributions to understanding eel biology and inform fisheries management strategies. By elucidating the biometric parameters associated with *A. bicolor*, this study aims to support the development of sustainable fishing practices and to promote conservation initiatives aimed at mitigating resource depletion (Wibowo et al., 2021). Furthermore, the insights gained from this research may provide a scientific foundation for future aquaculture endeavors, which are essential to reduce the reliance on wild eel populations while simultaneously addressing the growing market demand.

Furthermore, the current literature indicates that many eel populations, including A. bicolor, are facing significant threats from habitat degradation, climate change, and disease, particularly parasites such as *Anguillicoloides crassus*, which can alter the migratory capabilities of adult eels (Aschonitis et al., 2016). The impact of these factors on population dynamics has not yet been adequately studied, particularly in tropical regions such as Indonesia. Furthermore, while studies have examined the escapement and recruitment of European eels *A. anguilla*, similar comprehensive assessments for *A. bicolor* are lacking (McCarthy et al., 2013; Pujolar et al., 2014); this research aims to address these gaps by providing detailed biometric data and insight into the environmental conditions affecting *A. bicolor* in the Krueng Sawang River. By integrating biometric analysis with environmental assessments, this research aims to contribute to the sustainable management of eel populations and inform conservation strategies that are increasingly necessary in the face of global environmental changes.

Methods

Sampling procedure

The research on *A. bicolor* populations was conducted in the Krueng Sawang River area between April and May 2018. A survey-based methodological approach was employed to systematically collect and analyze biometric data, ensuring a comprehensive assessment of the species within the designated study area. The survey method was chosen due to its effectiveness in capturing population characteristics and ecological interactions, providing valuable insights into the species' distribution and morphological variation.

Sampling was carried out at three preselected stations, identified based on an extensive evaluation of environmental conditions and fish resource availability in the Krueng Sawang River. These stations were strategically chosen to represent variations in habitat structure, water quality, and eel population density. Collected specimens were carefully documented, measuring key biometric parameters such as length and weight to determine growth patterns and population structure.

Following field sampling, species identification and detailed morphological assessments were conducted at the Aquaculture Integrated Laboratory, Faculty of Agriculture, Universitas Malikussaleh. This laboratory-based analysis allowed for precise taxonomic classification and biometric evaluation, ensuring the accuracy of data interpretation.

Sampling location determination

The study was conducted at three strategically selected sampling stations within the Krueng Sawang River: Tanoh Anoe (Station 1), Gle Dagang (Station 2), and Babah Krueng (Station 3). These locations were chosen based on ecological attributes and anthropogenic influences to ensure a representative assessment of *Anguilla bicolor* populations. Specimens were collected using a combination of fishing rods and nets, allowing for a diverse and comprehensive sampling approach. The geographical distribution of the sampling stations is depicted in Figure 1.

Eel-collection procedure

Eel *A. bicolor* specimens were captured using a combination of nets and fishing rods to obtain a representative population sample. Following collection, the eels were transported to the laboratory for precise identification and biometric analysis.

Observation parameters

Biometric measurement

Biometric measurements of *A. bicolor* were conducted following standardized taxonomic identification protocols using authoritative reference materials, including Kottelat and Whitten (1996) and Nelson et al. (2016). These guidebooks provided a comprehensive framework for determining the taxonomic classification at the order, family, genus, and species levels. Morphometric parameters such as body shape, weight, total length, body height, coloration patterns, snout shape, fin morphology, fin count, and tail structure (Figure 2) were meticulously recorded.

The total length (TL) refers to the overall measurement of the fish from the tip of the snout to the end of the tail. The standard length (PS) is the length from the snout to the base of the tail, excluding the caudal fin. The body height (TB) is the vertical measurement of the fish at its highest point. The tail base length (PPE) represents the length of the narrow section just before the tail fin. The length in front of the dorsal fin (TSP) is the measurement from the snout to the starting point of the dorsal fin, while the length of the base of the dorsal fin (TSD) refers to the span of the dorsal fin attachment along the body. The length of the anal fin base (PPD) is the measurement of the fin along its attachment to the body. The pectoral fin length (PSD/PSP) is the length of the pectoral fin. The Head length (PK) is the distance from the snout tip to the posterior edge of the gill cover. The snout length (PM) refers to the distance from the front of the head to the eye. The eye diameter (LM) measures the size of the eye across its widest point. The tail base height (TPE) is the vertical measurement of the narrow section just before the tail. Lastly, the linea lateralis length (PLL) represents the length of the lateral line, an important sensory organ running along the body.

Relationship between fish length and weight

The relationship between the length and weight of the eels was analyzed using the Linear Allometric Model (LAM), as articulated by Cren (1951). The equation used for this analysis is expressed as follows:

$$W = aL^b$$

W represents the weight of the fish in grams (g), L denotes the length of the fish in millimeters, a is the linear regression

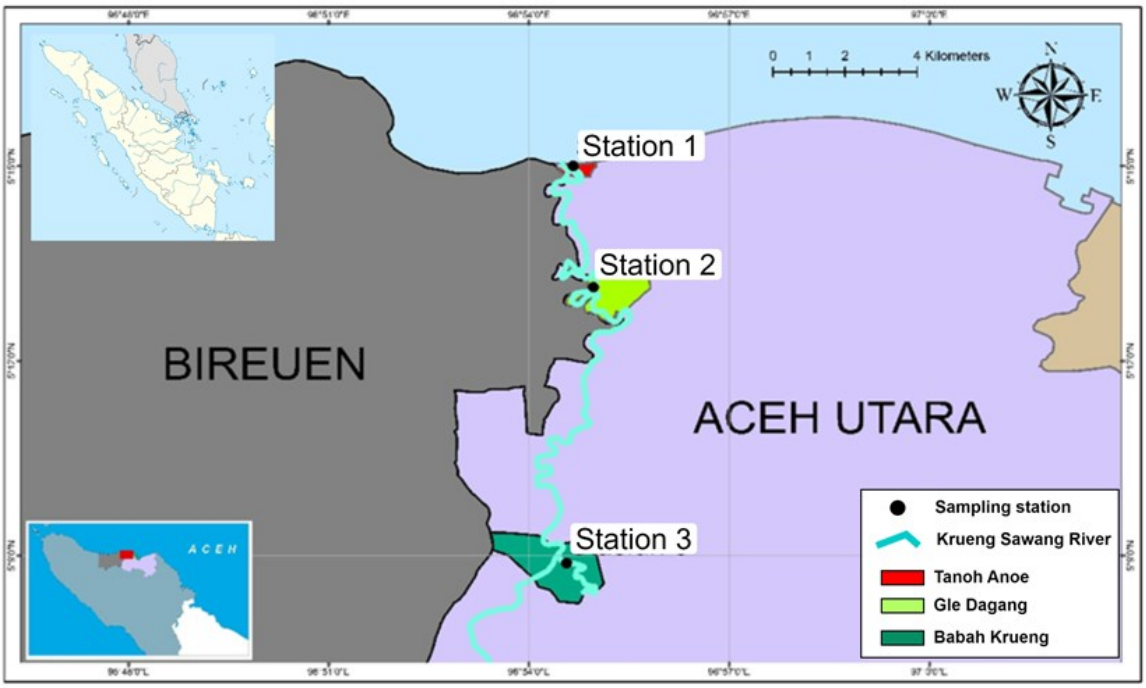

Figure 1. Eel *A. bicolor* sampling station.

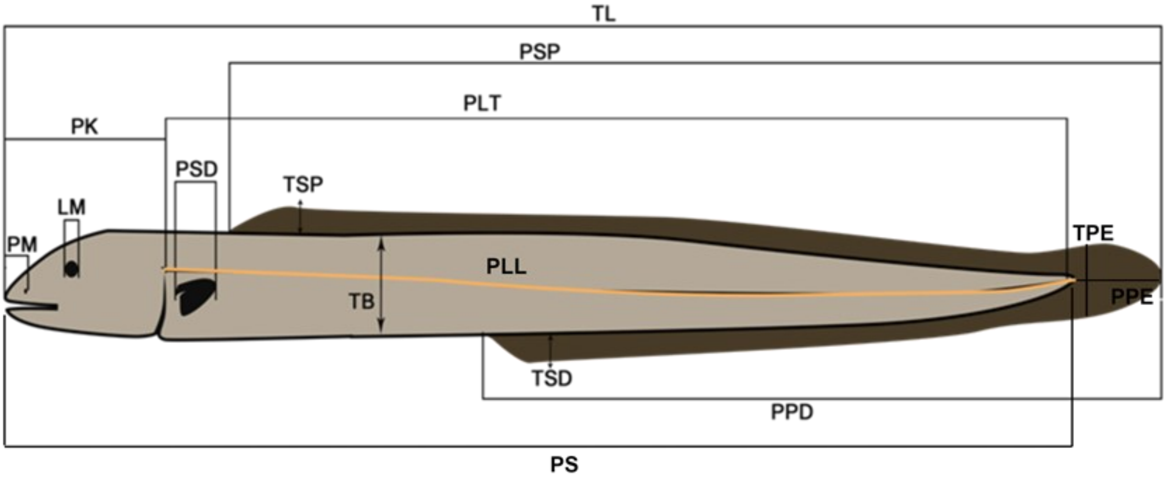

Figure 2. Schematic of biometric measurement of the eel. TL: Total length, PS: Standard length, TB: Body height, PPE: Tail base length, TSP: Length in front of the dorsal fin, TSD: Length of the base of the dorsal fin, PPD: Length of anal fin base, PSD: Pectoral fin length, PSP: Pectoral fin length, PK: Head length, PM: Snout length, LM: Eye diameter, TPE: Tail base height, PLL: Linea lateralis length.

intercept, and *b* is the regression coefficient. The value of *b* derived from this calculation serves as an indicator of the growth pattern exhibited by the fish. Specifically, if $b = 3$, the growth pattern is classified as isometric, indicating that the weight gain is proportional to the increase in length. On the contrary, if $b \neq 3$, the growth pattern is deemed allometric. Allometric growth patterns can be further categorized into positive and negative allometric growth. A value of *b* below 3 signifies negative allometric growth, where length increases at a faster rate than weight, while a value of *b* above 3 indicates positive allometric growth, where weight increases more rapidly than length (Karachle & Stergiou, 2012).

Water parameter

Water quality parameters were thoroughly measured alongside eel sampling to assess the environmental conditions influencing *A. bicolor* populations. Key parameters, including salinity, pH, temperature, and current velocity, were recorded to evaluate habitat suitability and its potential impact on eel health and distribution.

Data analysis

The data obtained from field observations and measurements were analyzed descriptively to elucidate the morphometric characteristics of the eels. This analysis was systematically organized and presented in the form of tables and figures, which serve to visually represent the findings and facilitate a clearer understanding of the relationships and trends identified in the data. The use of descriptive statistics is essential to summarise the data and provide information on the biological characteristics of the eel population in the Krueng Sawang River area.

Results

Characteristic of sampling station

Sampling was conducted at three intentionally selected stations, each characterized by distinct environmental and geographical features. Station 1, located in Tanoh Anoe (5° 15'00.0" N, 96°54'40.0" E), is positioned downstream, where the riverbed lacks significant rock formations and vegetation, resulting in turbid, yellowish water. Station 2, situated in Gle Dagang (5°13'07.9" N, 96°54'58.2" E), is in a residential and plantation-dominated area with densely vegetated riverbanks and murky waters. Station 3, found in Babah Krueng (5°08'53" N, 96°54'34" E), is influenced by a 20-meter-wide dam used for irrigation, with riverbanks containing significant shrub growth.

Eel *A. bicolor* distribution

The distribution of *Anguilla bicolor* specimens was assessed through systematic sampling employing gear suited to each station's hydrological conditions. A total of 100 eels were collected, with variations in catch numbers observed across stations. Station 1 yielded 18 specimens, while Station 2 exhibited the highest abundance with 54 individuals. Station 3 contributed 28 specimens. Following capture, biometric measurements and morphological analyses were conducted to document interstation differences. Figure 3 presents the spatial distribution of captured specimens.

Biometric of eel *A. bicolor*

The collected specimens underwent detailed morphometric assessment, including body shape, caudal fin morphology, mouth structure, scale type, and pigmentation patterns (Table 1). The average biometric characteristics varied significantly among stations. At Station 1, captured eels exhibited an average total length of 50.17 cm and a mean weight of 237.78 g. Station 2 specimens were comparatively smaller, averaging

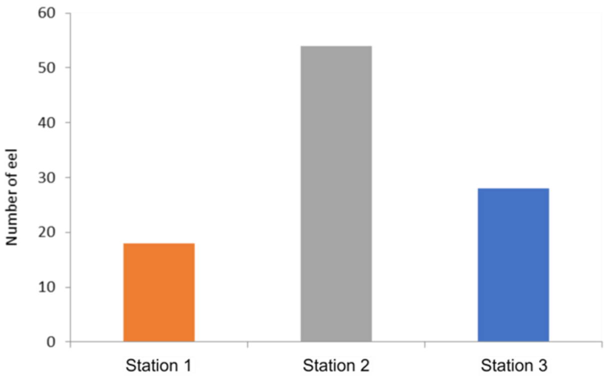

Figure 3. Number of *A. bicolor* caught at each station on the Krueng Sawang River.

31.96 cm in length and 135.93 g in weight. Station 3 specimens displayed intermediate values, with an average length of 35.18 cm and an average weight of 148.21 g. The morphometric characteristics are summarized in Table 2.

Table 1. General morphology of eel *A. bicolor* in the Krueng Sawang River.

Characteristic	Description
Body shape	Long (rope-like)
Tail fin shape	Tapered
Mouth location	Terminal
Mouth shape	Cannot be embossed
Scale type	Scaleless (slimy)
Body color	Brownish black

Table 2. Morphometric measurement of eel *A. bicolor* in the Krueng Sawang River.

Morphometric character	Unit	Station 1	Station 2	Station 3
		Mean	Mean	Mean
Total length	cm	50,17	31,96	35,18
Head length	cm	6,58	4,18	4,58
Eye diameter	cm	0,35	0,23	0,25
Snout length	cm	1,33	0,85	0,93
Pectoral fin	cm	2,02	1,29	1,42
Dorsal fin base length	cm	32,12	20,46	22,54
Dorsal fin	cm	3,56	2,28	2,51
Anal fin height	cm	4,53	2,89	3,18
Anal fin base	cm	29,22	18,54	20,43
Body height	cm	3,78	2,42	2,66
Linea lateralis	cm	41,65	26,55	29,21
Total weight	g	237,78	135,93	148,21

Length-weight relationship of *A. bicolor*

Regression analyses were performed to evaluate the relationship between length and weight across the three sampling stations. The length-weight relationship at Station 1 was expressed by the equation $y = 0.332x^{1.6752}$ ($R^2 = 0.8483$), indicating that approximately 88% of weight variation was attributable to length, with a negative allometric growth pattern ($b < 3$). Similarly, at Station 2, the regression equation $y = 1.907x^{1.2238}$ ($R^2 = 0.8379$) suggested that 83% of weight variation was explained by length, maintaining a negative allometric pattern. At Station 3, the equation $y = 1.9685x^{1.208}$ ($R^2 = 0.712$) indicated that length accounted for 71% of weight variation, also following a negative allometric trend. Figures 4a, 4b, and 4c illustrate these relationships.

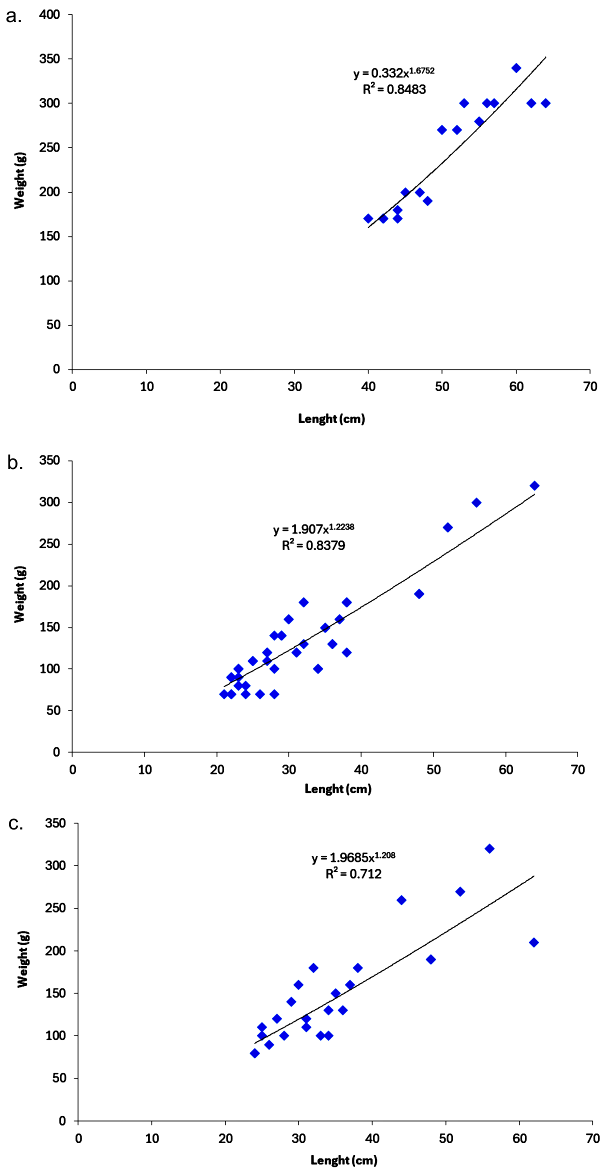

Figure 4. Length-weight relationship of *A. bicolor*. (a) Station 1 (Tanoh Anoe), (b) Station 2 (Gle Dagang), and (c) Station 3 (Babah Krueng).

Water parameter

Water quality parameters were systematically recorded at each station during sampling. Measurements were taken five times per station, including dissolved oxygen (DO), temperature, pH, and water current velocity. At Station 1, DO levels ranged from 5.23 to 6.74 ppm, pH varied between 6.8 and 7.4, temperature ranged from 27 °C to 30 °C, and water current velocity fluctuated between 4.74 s/m and 5.55 s/m. Station 2 exhibited DO levels between 6.11 and 7.65 ppm, pH values from 6.6 to 7.4, temperatures of 26 °C to 28 °C, and water current velocities of 4.21 to 5.63 s/m. Station 3 displayed DO levels from 6.40 to 7.94 ppm, pH values from 6.8 to 7.7, temperatures of 24 °C to 27 °C, and water current velocities of 3.15 to 4.42 s/m. These variations in physicochemical parameters likely influenced eel distribution and morphometric differences among stations.

Discussion

Eel distribution and habitat Influence

The distribution of *A. bicolor* eel fish at the three sampling stations in the Krueng Sawang River area reveals significant variability in catch numbers, with Station 2 producing the highest total of 54 eel. This distribution pattern may be influenced by several ecological factors, including habitat structure, food availability, and anthropogenic influences (Nero & Sealey, 2006). The higher number of eels captured at Station 2, characterized by community housing and plantations, suggests that human activities may improve habitat conditions favorable for the habitation of eels. For example, agricultural runoff can increase organic matter in the water, providing additional food sources for eels (Arai & Abdul Kadir, 2017). The presence of vegetation along the riverbanks can also contribute to the availability of food and shelter, as it supports a diverse array of invertebrates that serve as prey for eels (Shuai et al., 2020).

On the contrary, the lower catch at Station 1, despite its proximity to the river mouth, could indicate a less favorable habitat due to the absence of structural complexity, such as rocks and vegetation, which are important for providing shelter and foraging opportunities for eels (Piria et al., 2014). The lack of such habitat characteristics can lead to decreased foraging efficiency and increased vulnerability to predation, ultimately affecting the population dynamics of eels in this area. Additionally, the hydrological characteristics of the river, including the flow rate and the depth of the water, may also play a crucial role in determining the distribution of the eels. Eels are known to prefer habitats with slower currents where they can easily navigate and hunt for food (Nzau Matondo et al., 2023). Therefore, differences in habitat structure and hydrology between sampling stations can significantly influence the observed distribution patterns of *A. bicolor*.

Biometric and growth patterns

Biometric measurements of the eel fish revealed notable differences in size and weight between the specimens from the three stations. Station 1 exhibited the highest average length and weight, with eels averaging 50.17 cm and 237.78 g, respectively. This finding aligns with the idea that eels in downstream areas may have access to more abundant food resources and optimal growth conditions compared to those in upstream habitats (Nzau Matondo et al., 2023). The larger size of the eels at Station 1 can be attributed to the availability of diverse prey items and the potential for less competition in this area, allowing greater growth rates.

On the contrary, the smaller average size of eels at Station 2 (31.96 cm and 135.93 g) and Station 3 (35.18 cm and 148.21 g) suggests that these populations may be younger or experience growth limitations due to environmental stressors or competition (Capoccioni et al., 2013). The smaller size at these stations could also indicate that eels are in different stages of life, and those in upstream habitats could be younger and less developed than their downstream counterparts. The morphological traits assessed, including body shape and coloration, further support the idea that habitat influences the physical characteristics of eel populations (Falah et al., 2023). For example, eels in more vegetated areas may exhibit different coloration patterns that provide better camouflage against predators.

The average morphometric data collected from the eel fish samples at the three stations provide valuable information on the health and condition of the eel populations in the Krueng Sawang River area. The observed differences in size and weight can serve as indicators of the ecological health of the habitats and the availability of resources necessary for optimal growth. Monitoring these biometric parameters over time can help assess the sustainability of eel populations and inform conservation strategies aimed at preserving their habitats.

Length-weight relationship and growth dynamics

The analysis of the relationship between the length and weight of eel fish indicated a negative allometric growth pattern across all three stations, with coefficients of determination (R^2) ranging from 0.712 to 0.8483. This suggests that as the eels grow in length, their weight does not increase at the same rate, which is characteristic of many fish species in environments where food availability may fluctuate (Piria et al., 2014). The negative allometric growth observed at Station 1, with a regression coefficient *b* of 1.6752, indicates that these eels are elongating more rapidly than they are gaining weight, potentially reflecting a life stage where they are prioritizing length for migration or reproductive purposes (Arai & Chino, 2019). This growth strategy may be advantageous for eels as they prepare for their eventual migration to spawning grounds, where a larger body size can enhance reproductive success.

The findings from Station 2 and Station 3, with lower values of *b* further reinforce the idea that environmental conditions and resource availability play a critical role in shaping the growth patterns of eel populations (Yokouchi et al., 2021). The lower growth rates observed at these stations may indicate that eels face limitations in food availability or are subjected to higher levels of competition, which can impede their growth. Additionally, the negative allometric growth pattern may suggest that eels in these areas are adapting to their environments by a prioritizing length over weight, which could be a response to the specific ecological pressures they encounter.

The distribution and biometric measurements of *A. bicolor* across the sampling stations highlight the influence of habitat characteristics and environmental conditions on eel populations. The negative allometric growth pattern observed suggests that these eels adapt to their respective environments, which may have implications for their management and conservation in the context of changing ecological conditions. Understanding these dynamics is crucial for developing effective conservation strategies that address the specific needs of eel populations in the Krueng-Sawang River area.

Water quality assessment

The evaluation of water quality parameters in the Sawang River reveals critical insights into the ecological health of this aquatic system. The measured dissolved oxygen (DO) levels, pH, temperature, and water flow rates at three stations indicate a generally favorable environment for aquatic life, particularly fish, which is essential for the maintenance of biodiversity and ecosystem function. At Station 1, the DO ranged from 5.23 ppm to 6.74 ppm, while at Station 2, it varied from 6.11 ppm to 7.65 ppm, and at Station 3, it was between 6.40 ppm and 7.94 ppm. These values suggest that the river maintains adequate oxygen levels, which are crucial for fish survival and overall aquatic health. Research indicates that DO levels above 5 ppm are typically sufficient to support diverse fish populations, as they facilitate respiration and metabolism (Ali et al., 2022; Jia et al., 2020). The observed values in the Sawang River align with these findings, indicating a healthy aquatic environment.

The pH levels recorded from 6.6 to 7.7 at the stations are also within the acceptable range for freshwater ecosystems, which is generally between 6.5 and 9.0. This stability in pH is vital as it affects the solubility of nutrients and the overall biological activity within the water body (Banerjee et al., 2022; Deng et al., 2012; Xu et al., 2020). The pH values observed in the Sawang River suggest a balanced ecosystem, conducive to the growth and reproduction of aquatic organisms, including fish.

Temperature readings ranged from 24 °C to 30 °C, which are optimal for many species of freshwater fish (Fekri et al., 2018; Payne et al., 2016). Temperature influences metabolic rates, growth, and reproductive cycles in fish (Boltana et al., 2017; Little et al., 2020); therefore, maintaining temperatures within this range is beneficial for sustaining fish populations (Fangue et al., 2020). The thermal conditions in the Sawang River appear to support a productive aquatic ecosystem since higher temperatures can enhance growth rates, provided that other conditions, such as DO, are also favorable. The water flow rates, which ranged from 3.15 to 5.63 s/m, play a significant role in the ecological dynamics of the river. Flow velocity affects nutrient transport, habitat availability, and the migratory patterns of fish species (Hough et al., 2021; Tao et al., 2015). The observed flow conditions in the Sawang River suggest a dynamic environment that can support various stages of aquatic life, particularly during spawning migrations, which are critical to the sustainability of fish populations.

The water quality parameters measured in the Sawang River indicate a healthy ecosystem that supports fish life. The combination of adequate dissolved oxygen, stable pH, optimal temperature, and appropriate flow rates suggests that the river is conducive to sustaining diverse aquatic species. Continued monitoring and management of these parameters is essential to ensure the long-term health of the Sawang River ecosystem.

Conclusions

This study examined the distribution, biometric measurements, and growth patterns of eel fish (*A. bicolor*) in the Krueng Sawang River area of the North Aceh District. A total of 100 eels were collected from three sampling stations, with Station 2 producing the highest number of specimens, indicating favorable conditions due to human activities. Station 1 had the largest average size and weight, suggesting optimal growth conditions, while smaller sizes at Stations 2 and 3 may indicate growth limitations. The morphometric analysis revealed a negative allometric growth pattern, where the increase in length does not correspond proportionally to weight. This finding emphasizes the need for ongoing monitoring of eel populations to inform conservation strategies. Future research should focus on long-term monitoring of eel populations, the impact of environmental changes on their growth, and the effectiveness of habitat restoration efforts to support sustainable eel fisheries.

Acknowledgements

The authors would like to express their sincere gratitude to the Aquaculture Integrated Laboratory, Department of Aquaculture, Universitas Malikussaleh, for providing the necessary facilities and support throughout this research. We also extend our appreciation to the local fishermen around Krueng Sawang River for their valuable assistance in the eel catchment process, which contributed significantly to the success of this study. Their cooperation and insights were instrumental in obtaining the required data.

Authorship contribution

Mulyadi Mulyadi: Conceptualization, methodology, investigation, sample processing and analysis, visualization, original draft preparation, writing–review and editing. **Zulfikar Zulfikar:** Methodology, writing–review and editing, supervision. **Munawar Khalil:** Conceptualization, methodology, writing–review and editing, supervision.

Data availability

Datasets generated during and/or analysed throughout the present study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflict of interest.

Funding

No external funding or financial support was received while conducting this research.

References

Ali, B., Anushka, & Mishra, A. (2022). Effects of dissolved oxygen concentration on freshwater fish: A review. *International Journal of Fisheries and Aquatic Studies*, *10* (4), 113-127. https://doi.org/10.22271/fish.2022.v10.i4b.2693.

Arai, T., & Abdul Kadir, S. R. (2017). Diversity, distribution and different habitat use among the tropical freshwater eels of genus Anguilla. *Sci Rep*, *7*(1), 7593. https://doi.org/10.1038/s41598-017-07837-x.

Arai, T., & Chino, N. (2019). Variations in the migratory history of the tropical catadromous eels *Anguilla bicolor bicolor* and *A. bicolor pacifica* in south-east Asian waters. *J Fish Biol*, *94*(5), 752-758. https://doi.org/10.1111/jfb.13952.

Arai, T., Chino, N., Le, D. Q., & Harino, H. (2011). Life history-related organotin body burden in the catadromous eels *Anguilla marmorata* and *A. bicolor* pacifica in Vietnam. *Aquatic Biology*, *13*(2), 137-147. https://doi.org/10.3354/ab00358.

Aschonitis, V., Castaldelli, G., Lanzoni, M., Rossi, R., Kennedy, C., & Fano, E. A. (2016). Long-term records (1781–2013) of European eel (*Anguilla anguilla* L.) production in the Comacchio Lagoon (Italy): evaluation of local and global factors as causes of the population collapse. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *27*(2), 502-520. https://doi.org/10.1002/aqc.2701.

Banerjee, D., Chatterjee, S., & Nath, S. (2022). Aquatic physicochemical parameters and their possible impact on freshwater bodies. *Applied Ecology and Environmental Sciences*, *10*(6), 360-367. https://doi.org/10.12691/aees-10-6-5.

Boltana, S., Sanhueza, N., Aguilar, A., Gallardo-Escarate, C., Arriagada, G., Valdes, J. A., Soto, D., & Quinones, R. A. (2017). Influences of thermal environment on fish growth. *Ecol Evol*, *7*(17), 6814-6825. https://doi.org/10.1002/ece3.3239.

Capoccioni, F., Lin, D. Y., Iizuka, Y., Tzeng, W. N., & Ciccotti, E. (2013). Phenotypic plasticity in habitat use and growth of the European eel (*Anguilla anguilla*) in transitional waters in the Mediterranean area. *Ecology of Freshwater Fish*, *23* (1), 65-76. https://doi.org/10.1111/eff.12049.

Cren, E. D. L. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *The Journal of Animal Ecology*, *20*(2). https://doi.org/10.2307/1540.

Deng, M. H., Liu, K. B., & Luan, Z. Y. (2012). Study on flow and sediment diversion at four inlets of Dongting Lake and tendency and influences of erosion-deposition variation. *Applied Mechanics and Materials*, *212-213*, 10-19. https://doi.org/10.4028/www.scientific.net/AMM.212-213.10.

Falah, I. N., Adharini, R. I., & Ratnawati, S. E. (2023). Molecular identification of elvers (*Anguilla* spp.) from river estuaries in Central Java, Indonesia using DNA barcoding based on mtDNA CO1 sequences. *Jurnal Ilmiah Perikanan dan Kelautan*, *15*(1), 121-130. https://doi.org/10.20473/jipk.v15i1.36416.

Fangue, N. A., Todgham, A. E., & Schulte, P. M. (2020). Thermal Biology. In *The Physiology of Fishes* (pp. 91-104). CRC Press. https://doi.org/10.1201/9781003036401-7.

Fekri, L., Affandi, R., Rahardjo, M. F., Budiardi, T., Simanjuntak, C. P. H., Fauzan, T., & Indrayani, I. (2018). The effect of temperature on the physiological condition and growth performance of freshwater eel elver *Anguilla bicolor bicolor* McClelland, 1844. *Jurnal Akuakultur Indonesia*, *17* (2), 181-190. https://doi.org/10.19027/jai.17.2.181-190.

Hough, I., Moggridge, H., Warren, P., & Shucksmith, J. (2021). Regional flow–ecology relationships in small, temperate rivers. *Water and Environment Journal*, *36*(1), 142-160. https://doi.org/10.1111/wej.12757.

Hutchinson, A., Pons-Hernandez, M., & Ibáñez Alonso, A. (2024). Hungry for more: Examining how cultures of increasing demand drive the decline of the European eel. *International Journal for Crime, Justice and Social Democracy*. https://doi.org/10.5204/ijcjsd.3564.

Jia, Y., Wang, J., Li, J., Gao, Y., Guan, C., & Huang, B. (2020). Effect of dissolved oxygen on physiological functions and mechanism in fish. *Open Journal of Fisheries Research*, *7* (1), 8-14.https://doi.org/10.12677/OJFR.2020.71002.

Karachle, P. K., & Stergiou, K. I. (2012). Morphometrics and Allometry in Fishes. In C. Wahl (Ed.), *Morphometrics* (pp. 65-86). InTech. https://doi.org/10.5772/34529.

Karakoltsidis, P. A., & Constantinides, S. M. (2009). The eels, *Anguilla* spp., their characteristics and uses. *Food Reviews International*, *11*(2), 347-361. https://doi.org/10.1080/87559129509541045.

Kottelat, M., & Whitten, T. (1996). *Freshwater fishes of Western Indonesia and Sulawesi: Additions and corrections*. Periplus.

Little, A. G., Loughland, I., & Seebacher, F. (2020). What do warming waters mean for fish physiology and fisheries? *J Fish Biol*, *97*(2), 328-340. https://doi.org/10.1111/jfb.14402.

McCarthy, T. K., Nowak, D., Grennan, J., Bateman, A., Conneely, B., & MacNamara, R. (2013). Spawner escapement of European eel (*Anguilla anguilla*) from the River Erne, Ireland. *Ecology of Freshwater Fish*, *23*(1), 21-32. https://doi.org/10.1111/eff.12091.

Minegishi, Y., Gagnaire, P. A., Aoyama, J., Bosc, P., Feunteun, E., Tsukamoto, K., & Berrebi, P. (2011). Present and past genetic connectivity of the Indo�Pacific tropical eel *Anguilla bicolor*. *Journal of Biogeography*, *39*(2), 408-420. https://doi.org/10.1111/j.1365-2699.2011.02603.x.

Muchlisin, Z. A., Batubara, A. S., Fadli, N., Muhammadar, A. A., Utami, A. I., Farhana, N., & Siti-Azizah, M. N. (2017). Assessing the species composition of tropical eels (Anguillidae) in Aceh Waters, Indonesia, with DNA barcoding gene *cox1*. *F1000Research*, *6*, 258. https://doi.org/10.12688/f1000research.10715.1.

Nafsiyah, I., Nurilmala, M., & Abdullah, A. (2018). Nutrient composition of Eel *Anguilla bicolor bicolor* and *Anguilla marmorata*. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *21*(3). https://doi.org/10.17844/jphpi.v21i3.24733.

Nelson, J. S., Grande, T. C., & Wilson, M. V. (2016). *Fishes of the World*. John Wiley & Sons.

Nero, V. L., & Sealey, K. S. (2006). Fish–environment associations in the coastal waters of Andros Island, The Bahamas. *Environmental Biology of Fishes*, *75*, 223-236.

Nzau Matondo, B., Fontaine, F., Detrait, O., Poncelet, C., Vandresse, S., Orban, P., Gelder, J., Renardy, S., Benitez, J. P., Dierckx, A., Dumonceau, F., Rollin, X., & Ovidio, M. (2023). Glass eel restocking experiments in typologically different upland rivers: How much have we learned about the importance of recipient habitats? *Water*, *15*(17). https://doi.org/10.3390/w15173133.

Payne, N. L., Smith, J. A., van der Meulen, D. E., Taylor, M. D., Watanabe, Y. Y., Takahashi, A., Marzullo, T. A., Gray, C. A., Cadiou, G., Suthers, I. M., & Sinclair, B. (2016). Temperature dependence of fish performance in the wild: Links with species biogeography and physiological thermal tolerance. *Functional Ecology*, *30*(6), 903-912. https://doi.org/10.1111/1365-2435.12618.

Piria, M., Šprem, N., Tomljanović, T., Slišković, M., Jelić Mrčelić, G., & Treer, T. (2014). Length weight relationships of the European eel *Anguilla anguilla* (linnaeus, 1758) from six karst catchments of the Adriatic basin, Croatia. *Croatian Journal of Fisheries: Ribarstvo*, *72*(1), 32-35. https://doi.org/10.14798/72.1.704.

Pujolar, J. M., Jacobsen, M. W., Als, T. D., Frydenberg, J., Munch, K., Jonsson, B., Jian, J. B., Cheng, L., Maes, G. E., Bernatchez, L., & Hansen, M. M. (2014). Genome-wide single-generation signatures of local selection in the panmictic European eel. *Molecular Ecology*, *23*(10), 2514-2528. https://doi.org/10.1111/mec.12753.

Shuai, F., Liu, Q., Liu, Y., Wu, Z., Lek, S., & Chen, Y. (2020). Spatial distribution patterns of Japanese eels *Anguilla japonica* in a Large Subtropical River (Pearl River), China. *North American Journal of Fisheries Management*, *41*(4), 929-938. https://doi.org/10.1002/nafm.10420.

Sudo, R., Asakura, T., Ishikawa, T., Hatakeyama, R., Fujiwara, A., Inoue, K., Mochida, K., & Nomura, K. (2024). Transcriptome analysis of the Japanese eel (Anguilla japonica) during larval metamorphosis. *BMC Genomics*, *25*(1), 585. https://doi.org/10.1186/s12864-024-10459-z.

Tao, J. P., Tan, X. C., Yang, Z., Wang, X., Cai, Y. P., Qiao, Y., & Chang, J. B. (2015). Fish migration through a fish passage associated with water velocities at the Changzhou fishway (Pearl River, China). *Journal of Applied Ichthyology*, *31*(1), 72-76. https://doi.org/10.1111/jai.12634.

Tsukamoto, K., Chow, S., Otake, T., Kurogi, H., Mochioka, N., Miller, M. J., Aoyama, J., Kimura, S., Watanabe, S., Yoshinaga, T., Shinoda, A., Kuroki, M., Oya, M., Watanabe, T., Hata, K., Ijiri, S., Kazeto, Y., Nomura, K., & Tanaka, H. (2011). Oceanic spawning ecology of freshwater eels in the western North Pacific. *Nat Commun*, *2*. https://doi.org/10.1038/ncomms1174.

Wibowo, A., Antony, R., Samuel, S., Musch, A.-L., & Atminarso, D. (2021). Occurrences of Tropical Anguillids Eels Identified through DNA Barcodes at Kedurang River, Sumatra Island, Indonesia. *Indonesian Fisheries Research Journal*, *27*(2). https://doi.org/10.15578/ifrj.27.2.2021.91-98.

Wirth, T., & Bernatchez, L. (2003). Decline of North Atlantic eels: A fatal synergy? *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *270*(1516), 681-688. https://doi.org/10.1098/rspb.2002.2301.

Xu, Z., Li, C., Li, A., You, Z., Yao, W., Chen, Y., & Huang, L. (2020). Morphological characteristics of Cambodia Mekong Delta and Tonle Sap Lake and its response to river-lake water exchange pattern. *Journal of Water Resource and Protection*, *12*(04), 275-302. https://doi.org/10.4236/jwarp.2020.124017.

Yokouchi, K., Itakura, H., Wakiya, R., Yoshinaga, T., Mochioka, N., Kimura, S., & Kaifu, K. (2021). Cumulative effects of low‐height barriers on distributions of catadromous Japanese eels in Japan. *Animal Conservation*, *25*(1), 137-149. https://doi.org/10.1111/acv.12725.