

Feeding ecology of *Ali-ali* (*Glyptothorax* spp.) in the upper stream region of the Jambo Aye sub-watershed, Aceh, Indonesia

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Abstract

Glyptothorax spp., locally known as Ali-ali, is a native freshwater fish in the Jambo Aye sub-watershed, Wih Delong, Bener Meriah, Aceh, Indonesia. This study assessed its feeding ecology and selected ecological traits from December 2023 to February 2024. Sampling was conducted at three habitat-representative stations using gill and cast nets, yielding 90 individuals. Stomach content analysis revealed a predominantly carnivorous diet, dominated by crustaceans (72%), followed by macrozoobenthos (19%) and detritus (9%), with Index of Preponderance exceeding 40%, confirming crustaceans as principal prey. Length-frequency analysis identified eight size classes, with mean lengths highest at the plantation station (130.95 mm) and lowest in the forest station (92.19 mm). Mean relative gut length (RGL = 0.6 TL) supported carnivorous classification. Trophic niche breadth ranged between 1.30–2.17, indicating moderate resource-use variation. Length–weight relationships showed negative allometric growth ($b < 3$) and strong positive length–weight correlations ($r = 0.695–0.979$). Findings indicate stable trophic positioning, spatial size variation, and growth patterns reflecting adaptation to heterogeneous headwater habitats.



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Introduction

Upland river systems represent structurally complex freshwater environments characterised by high current velocity, coarse substrates, and spatially heterogeneous resource distribution. These physical attributes regulate benthic community structure and strongly influence trophic organisation within lotic ecosystems. In such habitats, rheophilic fishes exhibit morphological and functional adaptations that reflect energetic constraints imposed by hydrodynamic forces and substrate composition (Hrbek *et al.*, 2018). Consequently, trophic ecology provides a fundamental framework for understanding how benthic fishes acquire energy, partition resources, and maintain population stability under dynamic environmental conditions (Braga *et al.*, 2012; Brodeur *et al.*, 2017).

The Wih Delong River, located in Bener Meriah Regency, Aceh Province, Indonesia, is a fast-flowing mountain stream forming part of the Jambo Aye sub-watershed. This river supports diverse freshwater fish assemblages and contributes to subsistence fisheries for surrounding communities. Previous surveys have documented the presence of several native taxa within this system, including representatives of Anguilliformes, Cyprinidae, *Homaloptera gymnogaster*, *Cyclocheilichthys apogon*, *Channa gachua*, *Rasbora* spp., and *Glyptothorax* spp. (Muchlisin *et al.*, 2015; Hidayat *et al.*, 2023). Despite this documented diversity, detailed ecological assessments focusing on trophic structure and feeding specialisation remain limited.

Species of the genus *Glyptothorax* (family Sisoridae) are widely distributed across south and south-east Asia and are typically

associated with torrential mountain streams. These benthic catfishes exhibit distinct morphological adaptations, including dorsoventrally flattened bodies and thoracic adhesive apparatuses that enable attachment to rocky substrates under strong current conditions (Ng and Kottelat, 2016; Freyhof *et al.*, 2021; Mousavi-Sabet *et al.*, 2021). Such morphological specialisation is generally linked to substrate-oriented foraging behaviour and may constrain dietary breadth in high-gradient environments (Kliemann *et al.*, 2025). However, although *Glyptothorax* species are broadly distributed within the oriental region, ecological and biological information from tropical freshwater systems in Indonesia remains scarce.

This information gap is particularly significant given the increasing ecological pressures affecting upland river ecosystems. Habitat fragmentation, land-use conversion, sedimentation, and localised exploitation can modify benthic prey availability and alter trophic interactions (Abdan and Sulistiono, 2023; Abdan *et al.*, 2025). Changes in prey composition and habitat structure may directly influence trophic niche width and energy allocation patterns, particularly in benthic specialists that rely on structurally stable substrates (Wang *et al.*, 2019; Carcedo *et al.*, 2024). Therefore, baseline knowledge of diet composition, trophic niche breadth, and growth characteristics is essential for evaluating ecological resilience and informing conservation oriented management.

Quantitative analysis of stomach contents enables assessment of diet composition and resource dominance, while trophic niche breadth indices provide insight into the degree of feeding specialisation and potential resource partitioning within populations. In addition, relative gut length (RGL) offers functional interpretation of feeding type by relating digestive tract morphology to dominant dietary components. When combined with length–weight relationships, which reflect growth pattern and somatic energy allocation (La Mesa and Cali, 2025), these metrics provide an integrated perspective on trophic adaptation in lotic environments. Previous investigations on tropical freshwater

fishes such as *Tor tambra* (Muchlisin *et al.*, 2015), *Channa striata* (Khaing and Khaing, 2020; Putriani *et al.*, 2023), and *Puntius binotatus* (Pang *et al.*, 2024) have demonstrated the value of such integrated approaches in describing feeding strategies and ecological roles.

Nevertheless, no published study to date has specifically examined the dietary ecology, trophic niche characteristics, relative gut length, and growth pattern of *Glyptothorax* spp. in the Wih Delong River. The absence of these data limits ecological interpretation of benthic fish adaptation in high-gradient tropical streams and constrains the development of science based conservation and domestication strategies for native species.

Accordingly, this study aims to characterise the diet composition of *Glyptothorax* spp.; quantify trophic niche breadth across sampling stations; determine relative gut length as an indicator of feeding type, and analyse length–weight relationships to describe growth pattern in a mountainous stream environment. By integrating dietary composition, niche metrics, digestive morphology, and growth parameters, this research provides baseline ecological information for a benthic rheophilic species inhabiting an understudied upland river system, thereby contributing to future conservation planning and sustainable utilisation of native freshwater fishes.

Materials and methods

Study area and sampling design

This study was conducted from December 2023 to February 2024 in the Wih Delong River, a high-gradient tributary of the Jambo Aye sub-watershed located in Bener Meriah District, Aceh Province, Indonesia (Fig. 1). The river is characterised by fast-flowing sections with predominantly rocky substrates and varying riparian land-use patterns along its course.

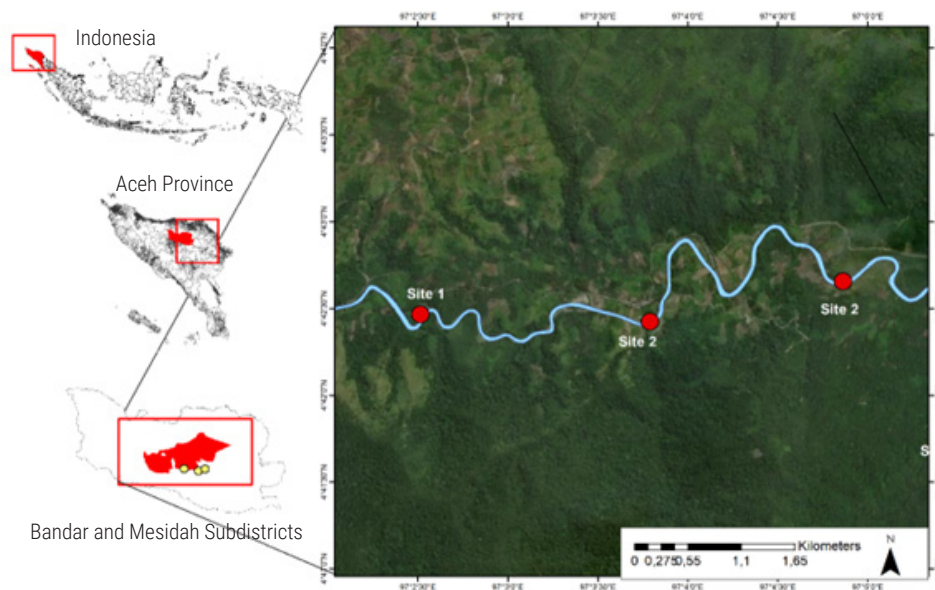


Fig. 1. Map showing the sampling sites of *Glyptothorax* spp. in the Wih Delong River, Bener Meriah District, Aceh Province

Three sampling stations were selected to represent contrasting riparian characteristics along the river continuum: Station 1 (plantation dominated area), Station 2 (residential area), and Station 3 (forested area). The selection of stations was intended to capture spatial variation in habitat conditions rather than to serve as statistically independent treatments.

At each station, 30 individuals of *Glyptothorax* spp. were collected, resulting in a total of 90 specimens. Sampling was conducted between 09:00 and 16:00 hrs Western Indonesian Time (WIB) using gill nets with mesh sizes of 0.5", 1.0", and 1.5", as well as a cast net (6 m diameter; 0.5" mesh size). The use of multiple mesh sizes was intended to reduce size selective bias. All specimens were euthanised and preserved in 4% formalin for subsequent stomach content and morphometric analyses.

Stomach content analysis and gut morphometrics

Laboratory analyses were conducted at the Fish Health and Environmental Laboratory, Fish Hatchery Centre, Lukup Badak, Central Aceh. Each specimen was dissected longitudinally from the anus toward the anterior region to remove the digestive tract. Total length (TL) and gut length (GL) were measured using a digital caliper. Relative gut length (RGL) was calculated following (Gupta, 2011):

$$\text{RGL} = \text{GL (mm)} / \text{TL (mm)}$$

where, $\text{RGL} < 1$ indicates carnivorous tendency, $\text{RGL} 1-3$ indicates omnivorous tendency, and $\text{RGL} > 3$ indicates herbivorous tendency.

Stomach contents were examined under a compound microscope. Food items were identified to the lowest feasible taxonomic level. For each food category, frequency of occurrence (O_i) and volumetric contribution (V_i) were recorded. Volumetric estimation was conducted using a graduated cylinder for measurable fractions. The Index of Preponderance (IP) was calculated following Effendie (2002):

$$\text{IP} = (V_i \times O_i) / \sum (V_i \times O_i) \times 100\%$$

Based on IP values, food items were categorised as: Main food: $\text{IP} > 40\%$, Supplementary food: $\text{IP} 4-40\%$, Incidental food: $\text{IP} < 4\%$.

Trophic niche breadth

Dietary diversity was quantified using Levins' niche breadth index (Ebert and Bizzarro, 2007):

$$B = 1 / \sum p_j^2$$

where, p_j represents the proportional volumetric contribution of food item j in the overall diet. To allow comparison across stations, standardised niche breadth (BA) was calculated:

$$\text{BA} = (B - 1) / (n - 1)$$

where, n is the total number of food categories recorded. BA ranges from 0 to 1, with higher values indicating broader trophic niche utilisation.

Length-weight relationship

The length-weight relationship (LWR) was analysed using the logarithmic transformation of the equation described by (Effendie, 2002):

$$\log W = \log a + b \log L$$

where, W is body weight (g), L is total length (mm), and a and b are regression coefficients. Growth pattern was interpreted based on the estimated value of b relative to 3, where: $b=3$ indicates isometric growth, $b>3$ indicates positive allometric growth, $b<3$ indicates negative allometric growth. Regression analysis and descriptive statistical summaries were performed using Microsoft Excel.

Results

A total of 90 specimens of *Glyptothorax* spp. were collected from three sampling stations representing plantation (Station 1), residential (Station 2), and forest (Station 3) habitats in the Wih Delong River.

Diet composition

Stomach content analysis identified three main food categories: crustaceans, macrozoobenthos, and detritus. Crustaceans constituted 72% of total dietary items, followed by macrozoobenthos (19%) and detritus (9%) (Fig. 2). This proportional pattern was observed across sampling stations and months.

The Index of Preponderance (IP) values showed that crustaceans exceeded 70% in males and 80% in females (Fig. 3). Macrozoobenthos fell within the supplementary category ($\text{IP} 4-40\%$), while detritus was categorised as incidental ($\text{IP} < 4\%$). Across size class intervals, crustaceans remained the dominant dietary component, although proportional contributions varied among length classes.

Length distribution

Length-frequency analysis grouped individuals into eight size intervals (Fig. 4). The highest mean total length was recorded at Station 1 (130.95 mm), while the lowest mean total length was recorded at Station 3 (92.19 mm). Size distribution patterns differed among stations, with smaller size intervals more frequently observed at Station 3.

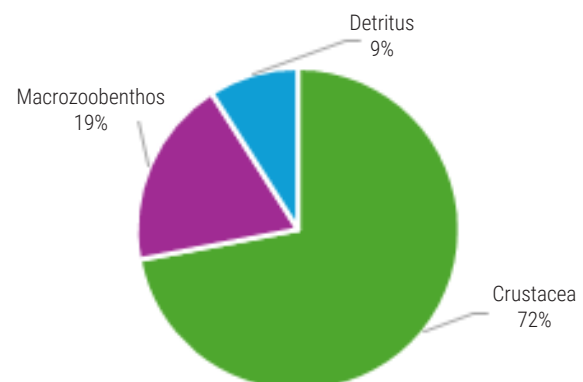


Fig. 2. Composition of natural diet items found in the stomachs of *Glyptothorax* spp. collected from Wih Delong River.

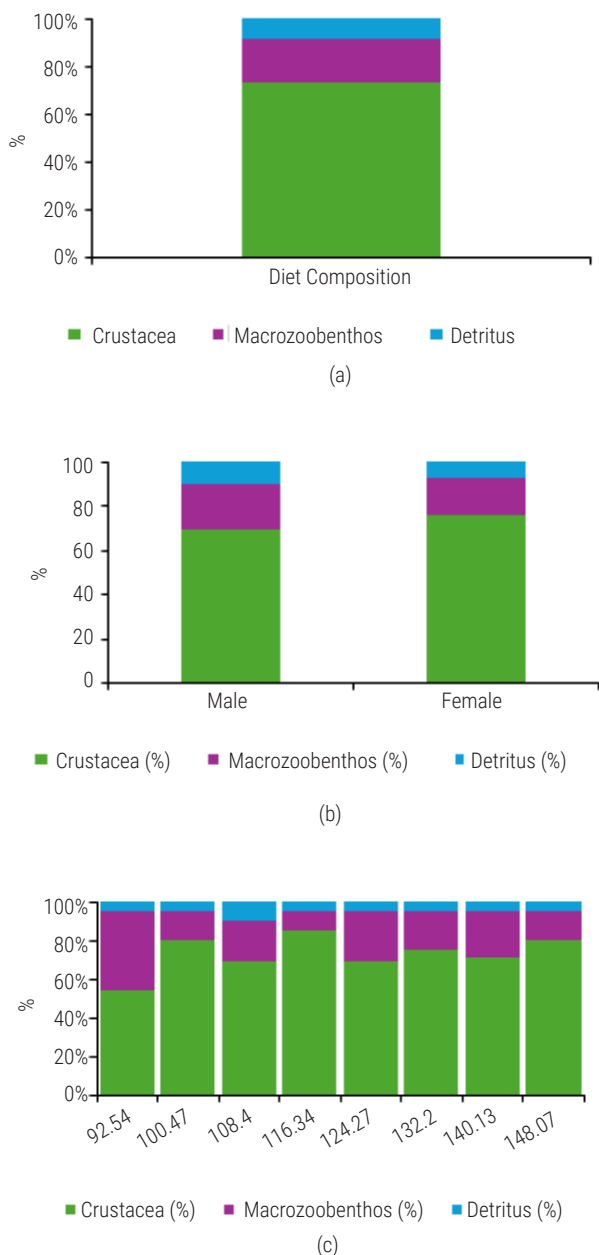


Fig. 3. Index of Preponderance of *Glyptothorax* spp. (a) Combined sexes; (b) Male and female, and (c) Based on size class intervals.

Relative gut length (RGL)

The average relative gut length (RGL) was 0.6 relative to total body length (Fig. 5). RGL values across stations and size classes were consistently below 1.

Trophic niche breadth

Levins' niche breadth (B) values ranged from 1.30 to 2.17 across size intervals (Table 1). The highest B value (2.17) was recorded in the 92.54 mm interval, while the lowest value (1.30) occurred in the 116.34 mm interval.

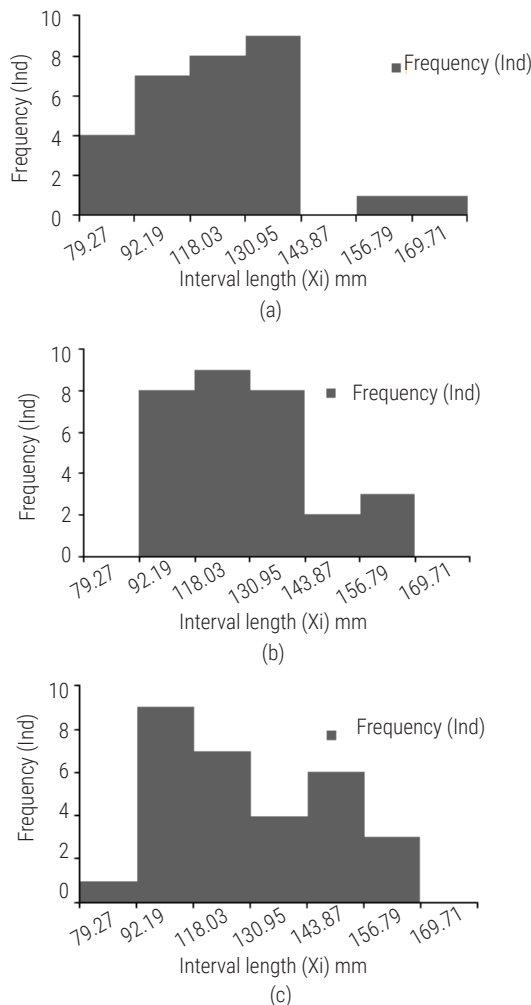


Fig. 4. Length size distribution of *Glyptothorax* spp. across sampling stations: (a) Plantation (Station I), (b) Residential area (Station II), and (c) Forest (Station III).

Table 1. Trophic niche breadth (B) and Interval length of *Glyptothorax* spp. across size classes.

Interval length (mm)	Niche breadth (mm)
92,54	2,17
100,47	1,48
108,40	1,84
116,34	1,30
124,27	1,80
132,20	1,75
140,13	1,73
148,07	1,47

Length-weight relationship

Length-weight analysis produced b values below 3 at all sampling stations, Station 1: $b=2.254$, Station 2: $b=2.591$, Station 3: $b=2.806$. Correlation coefficients (r) ranged from 0.6952 to 0.9785 across stations (Fig. 6), indicating positive associations between total length and body weight.

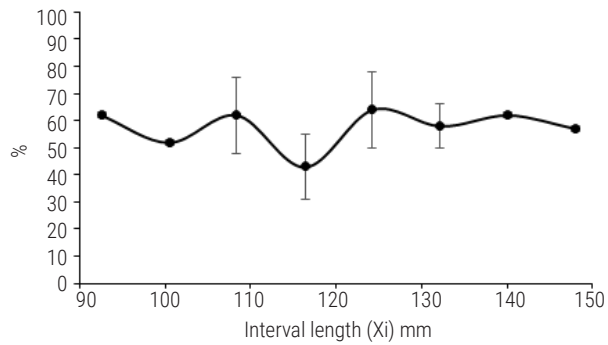


Fig. 5. Relative gut length (RGL, mm) of *Glyptothorax* spp. across sampling stations.

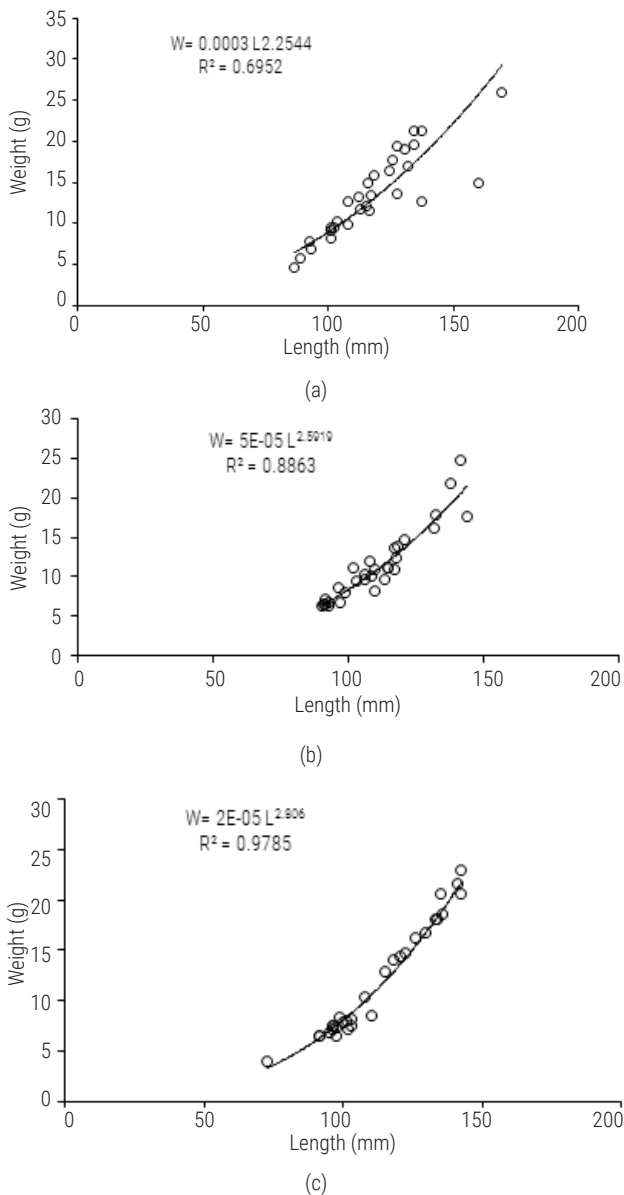


Fig. 6. Length–weight relationship of *Glyptothorax* spp. collected from three sampling stations: (a) Plantation (Station I), (b) Residential (Station II), and (c) Forest (Station III).

Discussion

Diet structure and trophic strategy

The predominance of crustaceans in the stomach contents of *Glyptothorax* spp. indicates structured prey use rather than incidental feeding. In high-gradient headwater systems, benthic macroinvertebrates commonly represent the primary energy conduit linking basal production to higher trophic levels (Rosas *et al.*, 2020; Atapaththu, 2023). The consistent dominance of crustaceans across stations and size classes therefore reflects sustained reliance on a benthic energy pathway characteristic of rheophilic stream fishes. Dietary concentration on a dominant prey category is often interpreted as trophic specialisation in structurally stable lotic environments (Wang *et al.*, 2018; Rusu *et al.*, 2025). However, the niche breadth values observed here do not indicate extreme restriction, but rather focused exploitation of a consistently available resource. The feeding pattern is thus better described as context-dependent specialisation, where trophic behaviour aligns with a spatially stable prey field.

Comparable patterns have been reported in upland tropical rivers, where crustaceans and other benthic invertebrates dominate the diets of carnivorous freshwater fishes (Pusey *et al.*, 2025). Recent studies further emphasise the central role of benthic macroinvertebrates in structuring trophic organisation in tropical headwaters (Parreira De Castro *et al.*, 2016; Wakhid *et al.*, 2020; Hafiane *et al.*, 2023). Collectively, these findings position *Glyptothorax* spp. as a benthic oriented predator occupying a relatively defined trophic role within the Wih Delong headwater food web.

Relative gut length and feeding strategy

The mean relative gut length (RGL) of 0.6, consistently below unity, places *Glyptothorax* spp. within the carnivorous trophic category based on established morphological thresholds (Rankins *et al.*, 2023). Short digestive tracts are typically associated with protein-rich diets requiring comparatively limited enzymatic processing (Jiao *et al.*, 2023). The crustacean-dominated diet aligns closely with this morphological configuration. Protein-based benthic prey are efficiently processed within compact gastrointestinal systems, a trait widely documented in invertivorous freshwater fishes (Lingopa *et al.*, 2022; Domínguez-Cisneros *et al.*, 2023). The convergence between stomach content analysis and RGL measurements strengthens the functional interpretation of *Glyptothorax* spp. as a benthic carnivore.

Minimal variation in RGL across stations further suggests that digestive morphology is relatively conserved within the spatial scale examined, rather than highly plastic in response to localised habitat differences. Similar morphology–diet congruence has been documented in benthic stream fishes inhabiting structurally stable lotic systems (Côte *et al.*, 2022; Endo, 2024). The integration of morphological and dietary evidence therefore provides robust support for classifying the species as a substrate-associated predator within the headwater trophic network.

Spatial variation in population structure

Variation in length distribution among stations indicates spatial structuring within the population. In tropical headwater streams, size-frequency differences are commonly linked to microhabitat

heterogeneity, including flow regime, substrate composition, and refuge availability (Choi *et al.*, 2021; Tan *et al.*, 2021; de Carvalho and Tejerina-Garro, 2022; Maroda and Sály, 2023). Although environmental variables were not quantified, the divergence in size classes suggests that localised habitat conditions may influence recruitment, growth, or survival. Notably, spatial differences in size structure were not accompanied by shifts in primary diet composition. Crustaceans remained the dominant prey across stations and size intervals, indicating trophic stability despite demographic heterogeneity. Similar decoupling between population structure and prey dominance has been reported in benthic stream fishes inhabiting systems where prey availability is consistently substrate associated (Morita *et al.*, 2024).

These findings suggest that, at the spatial scale examined, habitat heterogeneity shapes population organisation more strongly than trophic role. *Glyptothorax* spp. maintains a conserved benthic feeding strategy even where demographic structure varies, reinforcing its ecological positioning as a functionally stable invertivore within the headwater system.

Trophic niche breadth and ontogeny

The estimated trophic niche breadth values indicate moderate resource use within the population. Slightly broader niche breadth in smaller individuals suggests limited dietary expansion during early growth stages, a pattern consistent with ontogenetic adjustments in gape size, prey handling, and energetic demand (Tesfaye *et al.*, 2025; Deary *et al.*, 2017; Murchie *et al.*, 2019). However, crustaceans remained dominant across all size classes, indicating refinement rather than categorical trophic shifts. Smaller individuals appear to exploit a somewhat wider prey spectrum, whereas larger individuals concentrate more strongly on the dominant benthic resource. Comparable ontogenetic specialisation within a stable prey base has been observed in structurally persistent lotic systems (Kwak *et al.*, 2023).

The relatively narrow range of niche breadth values further suggests constrained trophic plasticity across growth stages. This pattern supports the interpretation that trophic organisation in the Wih Delong headwater segment is structured around a dominant benthic energy pathway. Within this context, ontogeny appears to involve progressive optimisation along a consistent feeding axis rather than functional reorganisation of trophic identity. Collectively, the results indicate moderate early-stage flexibility coupled with a conserved benthic-oriented feeding strategy throughout ontogeny.

Growth pattern and somatic allocation

The length–weight relationships revealed consistent negative allometric growth ($b < 3$) across stations, indicating that linear extension outpaced mass accumulation. In lotic systems, such patterns are frequently associated with morphological optimisation under sustained flow regimes rather than nutritional constraint (Abdan *et al.*, 2024; Bagley and Breitman, 2024; Nogueira De Carvalho *et al.*, 2025; Oladimeji *et al.*, 2025). Elongated body forms enhance hydrodynamic efficiency, reduce drag, and improve station-holding capacity in fast-flowing habitats (Sprinkle *et al.*, 2017). Within this biomechanical context, negative allometry may reflect somatic allocation aligned with habitat structure. In headwater segments dominated by rocky substrates and benthic

prey pathways, prioritising longitudinal growth could facilitate maneuverability within interstitial spaces and improve foraging efficiency. The strong length–weight correlations observed across stations indicate coherent somatic development at the population level (Colombo *et al.*, 2016; Khatun *et al.*, 2025).

Although minor spatial variation in b values occurred, these differences were not associated with dietary divergence, suggesting alignment between growth trajectory and trophic role across the examined gradient. In the absence of concurrent energetic or environmental measurements, mechanistic drivers cannot be definitively resolved. However, the spatial consistency of negative allometry supports interpretation as a stable growth strategy characteristic of this headwater population rather than localised physiological stress (Griffen *et al.*, 2018; Stallings *et al.*, 2023; Xu and Arranz, 2023).

Interpretation of these findings should consider several constraints. Sampling was conducted within a single seasonal window, limiting inference regarding temporal variability in discharge, prey availability, and dietary composition. Seasonal replication would be necessary to evaluate trophic plasticity under fluctuating hydrological conditions. Diet analysis relied on morphological identification of stomach contents, which may underestimate highly digested or soft-bodied prey and does not quantify biomass or energetic contribution. Additionally, benthic macroinvertebrate availability was not measured, precluding direct assessment of prey selectivity. Environmental parameters such as flow velocity, substrate composition, and water chemistry were also not quantified, restricting mechanistic linkage between habitat heterogeneity and observed population structure. Despite these limitations, the integration of stomach content analysis, trophic niche breadth estimation, relative gut length, and length–weight relationships provides a coherent functional characterisation of *Glyptothorax* spp. within an understudied tropical headwater system. The study establishes a trophic and growth baseline that can inform future investigations incorporating seasonal replication, quantitative benthic surveys, and environmental covariates to more rigorously evaluate habitat-driven population dynamics.

This study provides a functional assessment of *Glyptothorax* spp. in the upper Wih Delong segment of the Jambo Aye sub-watershed by integrating diet composition, trophic niche breadth, relative gut length, and length–weight relationships. The species exhibits a consistently benthic-oriented feeding strategy dominated by crustaceans across stations and size classes. The relatively narrow trophic niche breadth and low relative gut length further confirm its classification as a substrate-associated invertivore structured around a dominant benthic energy pathway. Spatial variation in size structure was evident; however, this population heterogeneity did not correspond to substantial shifts in diet composition. Trophic positioning remained stable across stations, suggesting that habitat variation within the examined gradient influences population organisation more strongly than feeding role. Ontogenetic patterns indicate limited dietary expansion during early growth stages, followed by refinement within a consistent trophic axis rather than categorical shifts between feeding guilds. Negative allometric growth ($b < 3$) observed across stations reflects somatic allocation aligned with hydrodynamic constraints typical of lotic environments. The consistency of both trophic and growth patterns indicates an ecologically integrated strategy shaped by headwater

habitat conditions. Overall, *Glyptothorax* spp. functions as a benthic-dependent predator whose stability is closely linked to substrate integrity and macroinvertebrate community structure, providing a baseline for ecological understanding and habitat management in tropical headwater systems.

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