



# Feeding habits of the African big barb, *Labeobarbus intermedius* (Rüppell, 1836) (Pisces: Cyprinidae) in Beles River, Ethiopia

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## Abstract

*Labeobarbus intermedius* is a key fisheries species in Ethiopia, yet its feeding ecology in the Beles River, a critical tributary of the Blue Nile feeding the Grand Ethiopian Renaissance Dam (GERD), remains understudied. This study quantified the diet composition of *L. intermedius* using frequency of occurrence and volumetric analyses of gut contents from 457 specimens (total length: 11.6–49.3 cm; total weight: 18–1,491 g) sampled from fishers' catch between January and September 2023 at Digadam landing site. Detritus (42.1%) and phytoplankton (41.5%) dominated the diet, followed by macrophytes (7.2%), insects (4.3%), zooplankton (3.4%), and gastropods (1.5%). Pronounced ontogenetic dietary shifts occurred: smaller fish (< 25 cm TL) primarily consumed insects (28.5%), gastropods (26.8%), and zooplankton (19.9%), while larger individuals (> 35 cm TL) transitioned to macrophytes (30.1%), phytoplankton (23.5%), and detritus (23.1%). No significant seasonal dietary variation was detected. The dominance of low nutritional value detritus suggests reduced availability of high-quality prey, indicating potential ecological stress. These findings highlight trophic plasticity in *L. intermedius* and provide essential data for conservation in the Beles River ecosystem.

**Keywords:** Beles River, Detritivory, Feeding habits, *Labeobarbus intermedius*, Ontogenetic dietary shift

## Introduction

The genus *Labeobarbus* (Cyprinidae) is widespread across African freshwater systems, including numerous Ethiopian lakes (Cambray, 1983; Tesfaye & Wolff, 2014). Among its members, the African big barb, *Labeobarbus intermedius* (Rüppell, 1836),

occupies a wide range of habitats, from highland and rift-valley lakes to the Baro–Akobo, Genale–Wabeshebele, and Abay basins (Admassu & Dadebo, 1997; Tesfaye & Wolff, 2014). Notably, Lake Tana, in Ethiopia, supports an endemic species flock of large *Labeobarbus*, which distinguishes it from other highland lakes (Awoke et al., 2015; de Graaf et al., 2004). Outside of Tana,

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*L. intermedius* is common in rift-valley lakes such as Ziway and Hawassa, as well as other Ethiopian freshwater bodies (Tesfaye & Wolff, 2014). Its presence in diverse ecosystems underscores its ecological resilience and significance. Economically, *L. intermedius* contributes notably to local fisheries, accounting for approximately 9% of Ethiopia's annual catch (Tesfaye & Wolff, 2014).

*L. intermedius* from different Ethiopian lakes showed omnivorous feeding habits, mainly feeding on gastropods, phytoplankton, macrophytes, insects, detritus, and nematodes with the tendency to shift to piscivorey (feeding on fish) as it grows older (Admassu & Dadebo, 1997; Desta et al., 2006; Sibbing, 1998). The findings of Kassahun (2005) and Dadebo et al. (2013) from Lake Koka oppose the piscivores feeding habits of the fish, stating that the gut contents were composed of macrophytes detritus, insects, and nematodes.

A substantial body of information exists in regard to *L. intermedius* feeding behavior in various aquatic habitats of Ethiopia, such as Tana, Hawassa, and Koka lakes. Nevertheless, feeding ecology in riverine habitats of southwestern Ethiopia, especially concentrating on the Beles River, has not been sufficiently investigated. This ignorance is of paramount significance due to the fact that the Beles River is a vital tributary that feeds into the Blue Nile, with direct implications in regard to affecting the Grand Ethiopian Renaissance Dam (GERD) reservoir's ecological soundness. In addition, riverine habitats are also increasingly being subjected to anthropogenic pressures that could impact food web associations and pose negative influences on key fisheries such as *L. intermedius*. In this regard, recognizing the trophic ecology of *L. intermedius* is not only an academic pursuit but also of great importance in terms of being central to its effective conservation and management. Therefore, this research aimed to examine dietary composition, ontogenetic variations, and seasonal variations in the feeding behavior of *L. intermedius* in the Beles River. Area-specific information provides a foundation for developing targeted measures that could be aimed at ensuring that this valuable fisheries resource in the dynamic Blue Nile basin ecosystem is harvested sustainably.

## Materials and Methods

### Sampling site description

The study was conducted in the Beles River of Mandura District in the Metekel Zone of the Benishangul-Gumuz Regional State, Ethiopia. The sampling area is located 50 km to the west

of Gelgel Beles Town, which is the capital of Metekel Zone, at 11° 00'N latitude and 35° 45'E longitude. The Beles River flows around Gilgel Beles Town and Mankush (formerly Guba) District in Babizenda Kebele, 541 km and 696 km northwest of Addis Ababa, respectively (Fig. 1).

The shape of the catchments of the Beles River is elongated along the main course of the river, broadening towards the southwest as more tributary streams join the main river. The Beles River is fed by many rivers before it joins the River Abay (Blue Nile River), which is one of the largest rivers and also the river that makes the GERD. Abat Beles, Gilgel Beles, Durra, Ardi, Alaltu, Dondor, Qarsa, and Shar Rivers are the most important tributaries of the Beles River.

In the Beles River, there are 22 fish species belonging to 5 orders, 7 families, and 13 genera. Among the families, the Cyprinidae family comprised 10 species; *L. intermedius* is the dominant species among the family members (Getahun et al., 2020). According to Berie's (2007) report, different types of phytoplankton that are found in the Beles River include Cyanophyceae (cyanobacteria), Chlorophyceae (green algae), Bacillariophyceae (Diatoms), Dinophyceae (Dinoflagellates), Cryptophyceae (Cryptophyta), and Euglenophyceae (Euglenophyta). The river is basically dominated by large populations of rotifers, copepods, cladocerans, ostracods, and dipteran insects. The Ciliophorans, especially Paramecium, were also represented by quite a number of species (Berie, 2007).

### Fish sampling and data collection

Fish samples were purchased from the landings of the fishers for eight consecutive months (January to September 2023) consecutive months, including four during the dry season and four

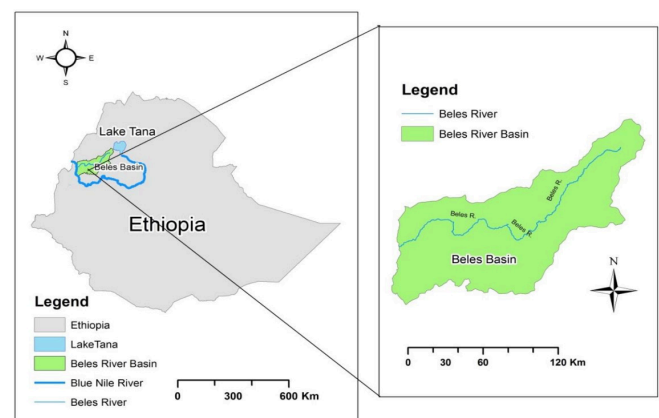


Fig. 1. The study area: Ethiopia on the right, Beles River on the left.

during the rainy season. Total length (TL), fork length (FL), and standard length (SL) were measured to the nearest 0.1 centimeter. The total weight (TW) was measured to the nearest 1 g. Gut contents of sampled fish were removed and preserved in a 5% formalin solution (Dadebo et al., 2013). The 5% formalin inhibits the decomposition of the samples.

### Gut content analysis

The gut contents were examined, and prey items were identified. Large food items, especially macrophytes (fruit), were identified visually; whereas, a dissecting microscope (MS5, magnification 10×; Leica, Wetzlar, Germany) and a compound microscope (magnification 100×; Leica DME, Wetzlar, Germany) were used to identify microscopic food items (Ademasu & Dadebo, 1997; Admassu et al., 2015; Dadebo et al., 2013; Desta et al., 2006). The relative importance and contribution of each food item to the diet of *L. intermedius* were determined using the standard methods, i.e., the frequency of occurrence method and volumetric analysis (Hyslop, 1980).

### Frequency of occurrence

The number of gut samples containing one or more of a given food item was expressed as a percentage of all non-empty guts examined from dissected fish (Bagenal & Braum, 1978). The proportion of the population that feeds on certain food items was estimated by this method as follows.

Frequency of occurrence (%FO) =

$$\frac{\text{Total number of guts with a particular food item}}{\text{Total number of guts with food}} \times 100$$

### Volumetric analysis

Each prey was classified into different taxonomic categories, and the volume of each prey item was measured. The volumetric percentage of each prey organism was then estimated visually, considering their size and abundance relative to the total food items in the sample droplet. The volume of each food category was expressed as a percentage of the total food categories present in the gut content sample, following the following equation. The importance of different food categories in relation to the size of fish was determined by categorizing the TL of the fish into different size classes and by observing the volumetric contribution of different food items to each size class (Bowen, 1983).

Volume analysis (%V) =

$$\frac{\text{Volume of one food item found in all sampled specimen}}{\text{The volume of all food items in all sampled specimens}} \times 100$$

### Ontogenetic dietary shift

Ontogenetic dietary shifts in *L. intermedius* were evaluated by quantifying the relative volumetric contribution of prey items across distinct size classes. Fish were grouped into eight total-length categories at 5 cm intervals, which were further consolidated into three broader classes: small (< 25 cm TL), medium (25–35 cm TL), and large (> 35 cm TL); to reduce misclassification, following the protocol of Dadebo et al. (2013). For each size category, the mean percentage volume of each prey type was calculated relative to the total gut content volume. These mean volumetric percentages served to illustrate how dietary composition changes as the fish grow.

### Estimation of seasonal diet composition

To examine seasonal variations in the diet of *L. intermedius*, an analysis was conducted separately for dry and wet months using frequency of occurrence and volumetric methods.

### Statistical analysis and interpretation

Data generated from the stomach contents were analyzed using Microsoft Excel. The frequency and volume of the food items were used in order to determine the percent contribution of each of the food items in the diet of *L. intermedius*.

## Results

### Diet composition

A total of 532 gut samples were analyzed, of which 75 (14.1%) specimens were found to be empty. The remaining 457 samples (85.9%) contained food items of both plant and animal origin. The plant-derived components included macrophytes, phytoplankton, and detritus, while animal-derived contents comprised insects, zooplankton, and gastropods. Among the insect prey, identifiable taxa included Chironomidae larvae, *Trichoptera*, *Anisoptera*, and *Ephemeroptera*.

### Frequency of occurrence

The frequency of occurrence showed that detritus and phytoplankton were found to be the most important food items, occurring in 90.6% and 87.7% of the guts, respectively (Table 1). The high frequency of occurrence of phytoplankton was mainly due to green algae. The others, next to detritus and phytoplankton, were macrophytes (fruit, bark, and root), followed by insects and gastropods occurring in 52.4%, 37.7%, and 30.2% of the guts examined, respectively, and zooplanktons (5.8%) were

**Table 1. Major food categories identified in the gut content of *Labeobarbus intermedius* in the Beles River**

Food item	Frequency	Percent	Volume	Percent
Phytoplankton	466	87.7	339.6	41.5
Zooplankton	30	5.8	19.9	3.4
Insect	201	37.9	26.9	4.3
Chironomidae	139	26.3	12.8	2.1
Ephemeroptera	77	14.5	5.4	0.86
Trichopteran	37	7.1	3.8	0.6
Anisoptera	41	7.8	4.9	0.78
Gastropods	161	30.3	12.3	1.5
<i>Melanoides</i>	124	23.3	6.5	0.78
<i>Bullinus</i>	95	17.8	5.8	0.72
Macrophytes	277	52	50.4	7.2
Roots	130	24.5	15.1	2.1
Shoots	108	20.3	9.6	1.4
Fruits	271	51.1	25.7	3.7
Detritus	482	90.6	344.3	42.1

less important than others in number. The high frequency of insects was due to Chironomidae larvae, followed by Ephemeroptera, and Anisoptera and Tricoptera, respectively, and the high frequency of gastropods was due to *Mellanoides* and *Bullinus*.

**Volumetric analysis**

Volumetrically, detritus was the most important food item, constituting 42.1% of the total volume, followed by phytoplankton with 41.5% of the total volume of the gut contents, respectively. Macrophytes (7.2%), insects (4.3%), zooplankton (3.4%), and gastropods (1.5%) constituted relatively low volumes compared to the above food categories (Table 1). Food items that contain insects, *Tricoptera*, and *Anisoptera* in high volume. The Gastropods (1.5%) were mainly contained in *Mellanoides* and *Bullinus*.

**Seasonal variation in the diet composition of the fish**

There was no significant variation in the types of food consumed by *L. intermedius* between the dry and wet months, although a slight difference was observed in the volumetric proportions of the diet. Overall, except for insects and detritus, the contributions of all food categories were slightly higher during the wet season. In contrast, the volumetric contributions of insects and detritus were greater during the dry season. Additionally, except for detritus and zooplankton, the frequency of occurrence of all food items increased during the wet months (Table 2).

**Table 2. Variation in seasonal diet composition of *Labeobarbus intermedius* in the Beles River (unit: %)**

Food item	Dry month		Wet month	
	Frequency	Volumetric	Frequency	Volumetric
Phytoplankton	74.4	39	86.9	43.6
Zooplankton	5.2	1	3.8	2.3
Insects	31.2	5.3	37.2	4.6
Gastropods	28.1	1.2	31.4	2.8
Macrophytes	61.3	7.6	63.8	7.9
Detritus	82.1	45.9	74.4	38.8

**Ontogenetic dietary shift**

The TL of *L. intermedius* specimens containing food items ranged from 11.6 cm to 49.3 cm. To facilitate analysis, individuals were categorized into eight 5-cm length classes. These classes were further consolidated into three broad size categories: small (< 25 cm TL), medium (25–35 cm TL), and large (> 35 cm TL). Significant ontogenetic shifts in dietary composition were observed across these size classes. The volumetric contribution of insects, gastropods, and zooplankton decreased markedly with increasing fish size. Insects constituted over 50% of the diet in individuals smaller than 15 cm TL. Conversely, consumption of other food categories, phytoplankton, detritus, and macrophytes, increased proportionally with size. Gastropods were also predominantly consumed by smaller fish (Fig. 2). This indicates a distinct dietary transition towards phytoplankton and macrophytes during growth.

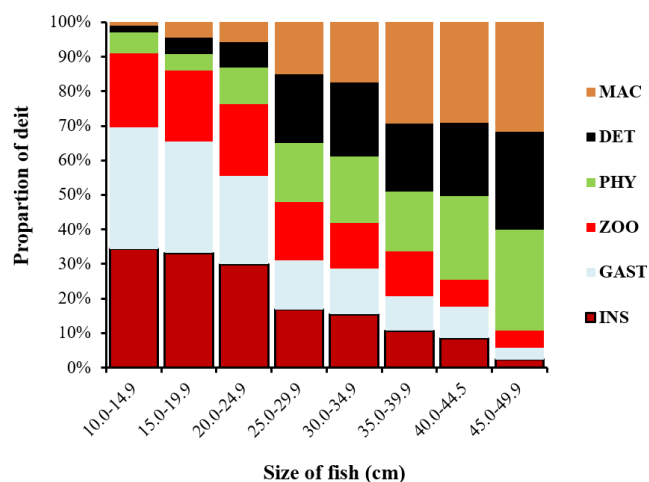
Quantitative diet analysis revealed the following volumetric contributions by size class:

According to Fig. 2, small (< 25 cm TL): insects (28.5%), gastropods (26.8%), zooplankton (19.9%), phytoplankton (9.6%), detritus (8.5%), macrophytes (6.6%). Medium (25–35 cm TL): detritus (20.7%), phytoplankton (18.2%), macrophytes (16.3%), insects (16.1%), zooplankton (15.1%), gastropods (13.7%). Large (> 35 cm TL): macrophytes (30.1%), phytoplankton (23.5%), detritus (23.1%), zooplankton (8.6%), gastropods (7.5%), insects (7.2%) (Fig. 2).

**Discussion**

**Food and feeding habits**

Of the 532 fish gut samples analyzed, 75 specimens (14.1%) were empty. This phenomenon may be attributed to prolonged retention in fishing gear before collection by fishers and subsequent transport to markets. Extended capture times can facili-



**Fig. 2. Ontogenetic dietary shift of *Labeobarbus intermedius* in the Beles River.** MAC, macrophytes; DET, detritus; PHY, phytoplankton; ZOO, zooplankton; GAST, gastropods; INS, insects.

tate gastric evacuation, regurgitation, or digestion of prey items, leading to an increased incidence of empty guts (Thormar et al., 2024). Based on the gut content analysis conducted in the present study, detritus, phytoplankton, macrophytes, insects, gastropods, and zooplankton were identified as significant food items, with their importance ranked from most to least dominant. Consistent with these findings, Dadebo et al. (2013) reported that *L. intermedius* in Lake Koka primarily feeds on detritus, phytoplankton, macrophytes, and insects. Similarly, another study has noted that the main food items of *L. intermedius* in Lake Koka include macrophytes, detritus, and aquatic insects (Kassahun, 2005).

Similarly, in Lake Tana, the diet of *L. intermedius* was dominated by benthic prey organisms, particularly insect larvae and detritus (de Graaf, 2003; Sibbing, 1998). Engdaw (2014) also reported a balanced intake of food items from both plant and animal sources. Kassahun (2005) and Dadebo et al. (2013) documented findings largely similar to those of the present study. However, the present study recorded fewer food categories than those reported by Kassahun (2005) and Dadebo et al. (2013). This difference may be attributable to variations in the sampling ecosystems, variations in the size classes of fish sampled, and the shorter sampling period in the present study. The divergent dietary compositions of *L. intermedius* across water bodies could be primarily driven by fundamental differences in habitat characteristics and prey communities. The evolution of piscivory is facilitated in Lake Tana due to its large size, deep depth

with a well-established pelagic zone, and abundant populations of small endemic barb species (Nagelkerke, 1997). In contrast, the shallower and more turbid lake, Lake Koka, or other riverine environments often lack these specific prey fish but support high biomass of benthic invertebrates and detritus, favoring an omnivorous strategy (Dadebo et al., 2014). Furthermore, agricultural runoff can eutrophy water bodies, shifting primary production towards phytoplankton and detritus, thereby further shaping the available forage base and subsequently the diet of opportunistic feeders like *L. intermedius*.

However, contrary to the present investigation, the findings of Admassu & Dadebo (1997) and Zerihun (2020) indicated that the primary dietary sources of *L. intermedius* were of animal origin and detritus, with macrophytes, phytoplankton, zooplankton, and ostracods being less important. These studies also reported that the fish exhibited piscivorous tendencies above 30 cm TL. Furthermore, Desta et al. (2006), Nagelkerke (1997), and Wakijira (2013) documented piscivorous feeding habits in *L. intermedius*, with diets including fish, ostracods, zooplankton, mollusks, aquatic insects, and algae. This represents a different dietary composition compared to the present study. Specifically, Nagelkerke (1997) noted that in Lake Tana, Ethiopia, five of eight large barb species were specialized piscivores, attributing this behavior to the abundance of *Barbus humilis* in littoral areas and *Barbus tanapelagi* in the pelagic zone. Similarly, Desta et al. (2006) reported that *L. intermedius* in Lake Hawassa was piscivorous, primarily preying on the small barb *Barbus paludinosus* due to its abundance in the littoral zone and the absence of other specialized piscivorous fish. The reported inconsistencies in the published diet of *L. intermedius* are not unusual but indicative of the high trophic plasticity of the species. The inconsistencies can largely be attributed to spatial and temporal differences in the occurrence of prey items, ontogenetic variations, and variations in methodology in the diet analysis (Desta et al., 2006; Hyslop, 1980; Nagelkerke, 1997).

The significant volumetric contribution and frequent occurrence of detritus in the guts of *L. intermedius* sampled in this study highlight its importance as a food source. While detritus is recognized as having low nutritional value (Bagenal & Braum, 1978; Bowen, 1979), its increased consumption in lotic and lentic ecosystems often indicates scarcity of more nutritious primary foods (Bowen, 1979; King et al., 2003). Therefore, the reliance on detritus observed here implies a decline in the availability of higher-quality food resources within the Beles River.

As a consequence, this strong reliance on detritus detected

in this research indicates reduced availability of higher-quality prey items (e.g., zooplankton, insects) in the Beles River. This shift in diet to one of reduced quality might be related to several ecological and anthropogenic factors. The Beles catchment is now under significant anthropogenic pressures, such as deforestation and agricultural encroachment (e.g., maize and sesame farming), that can lead to increased erosion and sedimentation (Berie, 2007). Such intensified sediment loads could exacerbate benthic habitats, suffocating gastropod and insect larval communities (King et al., 2003). In addition, runoff associated with farming is sure to carry fertilizers and pesticides into the riverine ecosystem. Fertilizers could augment phytoplankton biomass (perhaps explaining its high volumetric contribution), while pesticides might impact negatively upon zooplankton and macroinvertebrate numbers, because these are more sensitive toxins (Dadebo et al., 2013). Such possible factors are in accord with detected dietary habits and in line with documented impacts of land use changes upon global riverine food webs. This, therefore, indicates that *L. intermedius* trophic dynamics in the Beles River might act as a bioindicator of wider ecosystem disruption.

High ingestion of detritus, a resource usually having low nutritional value and high quantities of indigestible material (Bowen, 1979), has important ecological connotations for *L. intermedius* populations. Strong obligatoriness of detritivory usually requires a high ingestion rate in compensation for low assimilation of nutrients, hence high gut fullness but potentially low growth rate and reduced body condition (i.e., low weight-for-length) in comparison to populations whose diets are comprised of more protein-enriched sources like animal prey or water-column insects (Dadebo et al., 2013). The feeding strategy comes at a trade-off: while detritus is a ubiquitous and reliable resource base, resource consumption tends to define the maximum possible size and reproductive potential of individuals in the populations.

However, the feeding on detritus represents a major adaptive strategy promoting stable populations. In communities defined by the episodic or unpredictable nature of prey (such as seasonal insect emergences and fluctuating fish stocks), the exploitation of detritus represents a necessary 'fallback' resource. This allows *L. intermedius* to maintain a sustainable population density even without readily preferred, high-quality prey and hence augments the species' resilience and reduces the risk of catastrophic population declines (Zerihun, 2020). Consequently, the detritivory represented by this research very probably reflects a strategy geared more towards the persistence and sta-

bility of populations rather than the optimization of individual growth performance, a common adaptation in resource-limited or fluctuating freshwater ecosystems.

This study aimed to investigate potential differences in the diet of *L. intermedius* between the dry and wet sampling months. Our findings revealed slight differences in variation in either the types of food items consumed or their volumetric contributions between the two seasons. In contrast, Admassu & Dadebo (1997) reported a clear seasonal pattern, with insects, macrophytes, fish, and gastropods contributing significantly to the diet during the dry season, while insects dominated during the wet season. Similarly, Dadebo et al. (2013) observed a pronounced seasonal difference in the diet of *L. intermedius* in Lake Koka. Their study showed that detritus (34.0%) and insects (32.5%) made up the majority of the diet in the dry season, whereas macrophytes (66.1%) and detritus (24.0%) were predominant in the wet season. In the Gilgel Gibe Reservoir, Wakijira (2013) also reported that aquatic insects, detritus, and zooplankton were more abundant in the diet during the dry season, whereas macrophytes dominated during the wet season.

An ontogenetic dietary shift was observed in the diet of *L. intermedius* in the Beles River. Individuals less than 25 cm in TL primarily consumed insects (28.5%), gastropods (26.8%), and zooplankton (19.9%). In contrast, fish in the 25–34.9 cm TL range exhibited a more balanced diet, with insects (16.1%), gastropods (13.7%), zooplankton (15.1%), phytoplankton (18.2%), macrophytes (16.25%), and detritus (20.65%) contributing relatively equally to their overall diet. For individuals exceeding 35 cm TL, detritus (23.1%), phytoplankton (23.5%), and macrophytes (30.1%) were the dominant dietary components. These findings suggest that dietary preference in *L. intermedius* is influenced by mouth size and the fish's ability to process different food items efficiently. Consistent with the present study, Admassu & Dadebo (1997) documented distinct ontogenetic dietary shifts in *L. intermedius* from Lake Hawassa. They reported smaller fish (< 25 cm TL) primarily consumed insects and gastropods, while intermediate-sized fish (25–32 cm TL) fed approximately equally on insects, fish, gastropods, and macrophytes. Larger individuals (> 32 cm TL) were exclusively piscivorous, predominantly preying on *Oreochromis niloticus*. Similarly, Dadebo et al. (2013) observed pronounced ontogenetic dietary variation in Lake Koka: fish < 20 cm TL derived > 75% of their diet from detritus and insects, whereas those > 20 cm TL shifted to diets dominated (> 75% by volume) by macrophytes and detritus. This transition reflected declining

insectivory and increasing herbivory with fish size (Dadebo et al., 2013). These dietary shifts reduce intraspecific competition between size classes. As juveniles and adults target different prey, the population can more efficiently partition available resources, which supports higher overall population density and stability within the ecosystem.

Contrary to our findings, studies of *L. intermedius* in Lake Hawassa detected negligible dietary differences across size classes. Desta et al. (2006) found no significant ontogenetic variation, though smaller fish (< 15 cm TL) consumed slightly more insects, fish eggs, and ostracods, while larger fish (> 25 cm TL) consumed more gastropods, fish, and detritus. Zerihun (2020) corroborated this pattern, noting higher insect consumption in fish < 25 cm TL and increased gastropod and macrophyte intake in larger size classes (> 25 cm TL).

## Conclusion

The study reveals that *L. intermedius* in the Beles River is primarily detritivorous-phytoplanktivorous, with detritus (42.1%) and phytoplankton (41.5%) dominating its diet. Notable ontogenetic dietary shifts occur: smaller fish (< 25 cm TL) rely heavily on insects, gastropods, and zooplankton, while larger individuals (> 35 cm TL) transition to macrophytes, phytoplankton, and detritus. No significant seasonal variation was observed, indicating consistent resource utilization year-round. The dominance of low-nutritional-value detritus suggests reduced availability of high-quality prey, possibly reflecting ecological stress in the Beles River ecosystem. These findings highlight the species' adaptive trophic plasticity but underscore potential resource limitations in this critical tributary of the Blue Nile basin.

## Recommendations

Based on the results of the current investigation, the following points are recommended.

- Conservation measures: protect riparian vegetation and benthic habitats to maintain detritus and phytoplankton production, ensuring food security for juvenile and adult *L. intermedius*.
- Fisheries management: regulate fishing pressure on smaller size classes (< 25 cm TL), which exhibit higher vulnerability due to their specialized insect-based diet.
- Long-term monitoring: extend sampling duration to validate seasonal stability and assess impacts of climate or anthropogenic changes on food resources.

- Habitat restoration: investigate causes of reduced prey diversity (e.g., pollution, flow alterations) and restore degraded stretches to enhance prey availability.
- Comparative studies: expand research to other Blue Nile tributaries to evaluate regional dietary plasticity and inform basin-wide conservation strategies.

## Competing interests

No potential conflict of interest relevant to this article was reported.

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## Availability of data and materials

Upon reasonable request, the datasets used in this study can be made available from the corresponding author.

## Ethics approval and consent to participate

This study conformed to the guidance of animal ethical treatment for the care and use of experimental animals.

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