



Food and feeding habits of *Labeobarbus intermedius* in the recently built Ribb Reservoir, Northwest Ethiopia

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Abstract

Food and feeding habits of *Labeobarbus intermedius* were studied from the newly constructed Ribb Reservoir, Ethiopia during the dry (December–March) season and wet season (June–August) of 2021. The objective of the study was to determine the diet composition, seasonal variation, and ontogenetic dietary shift in the diets of the dominant cyprinid fish in Ribb Reservoir. In this study, frequency of occurrence and volumetric analysis methods were used to present the results. From a total of 203 fish samples, 132 (65%) guts contained food items. Macrophytes (29.4%), phytoplankton (27.2%), detritus (14.8%), and insects (13.6%) were the major food items in the diets volumetrically. During the dry season, *L. intermedius* was mainly dependent on phytoplankton (58.2%), insects (15.2%), and zooplankton (13.7%) volumetrically. Whereas, macrophytes (50.3%) and detritus (23.3%) were the dominant food items in the wet season. The frequency occurrence and volumetric contribution of the diets of *L. intermedius* varied significantly (χ^2 test, $p < 0.05$) between seasons. Schoener's diet overlap index revealed a slight ontogenetic dietary shift in the diets of *L. intermedius*. While insects, nematodes, and zooplankton were the main diets of small-sized *L. intermedius*, macrophytes and detritus were ingested by large-sized *L. intermedius*. Generally, *L. intermedius* fed both plant and animal-origin food items and is considered an omnivorous feeder in Ribb Reservoir.

Keywords: Diet composition, Ontogenetic dietary shift, Ribb Reservoir, Schoener's diet overlap index, Seasonal variation

Introduction

Labeobarbus intermedius (Rüppell, 1836) is an extensively distributed fish species in most parts of the Ethiopian catchments and Northern Kenya basins (Dadebo et al., 2013). It is widespread in the Ethiopian Rift valley, Abay, and Baro-Akobo basins of Ethiopia where Lake Tana hosts the largest population (Awoke,

2015; Vijverberg et al., 2012). However, despite the abundance and socioeconomic importance of *L. intermedius* in Lake Tana, the catches are now declining from time to time due to overfishing, habitat destruction, irrigation, and dam construction (de Graaf et al., 2000; Dejen et al., 2017; Gebremedhin et al., 2019; Mingist & Gebremedhin, 2016).

L. intermedius feeds on a variety of foods in various aquatic

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environments including zooplankton, phytoplankton, aquatic insects, fish, detritus, fish scales, nematodes, macrophytes, gastropods, fish eggs, fishes, mollusks, benthic invertebrates, insect larvae, and nematode (Dadebo et al., 2013; de Graaf et al., 2000; Deribe et al., 2011; Desta et al., 2006; Engdaw, 2014; Sibbing et al., 1994; Wakijira, 2013). Those studies also showed that there is a variation of food items within the same study area and fish species at different times of study. This is due to prey availability, season, habitat difference, and size of the fish (Desta et al., 2006; Sibbing & Nagelkerke, 2000).

Investigating the diet of fish species is a subject of ongoing research as it provides a basis for the developing of a successful management program for capture fisheries and aquaculture (Shalloof et al., 2009). In addition, the information on the natural foraging and feeding habits of fish species allows the identification of the trophic relationships present in the aquatic ecosystem and the identification of the food composition, structure, and stability of food webs in the ecosystem (Otieno et al., 2014). Such information is also important to guide the management of fish in the natural environment and within the controlled environment and the formulation of an acceptable diet for the fish in aquaculture (Adeyemi et al., 2009). Therefore,

understanding its food and feeding habits is a key factor to successful and sustainable fish farming in a controlled environment (Shalloof & Khalifa, 2009).

The Ribb Reservoir fishery started in 2018 and *L. intermedius* is one of the commercially most important fish species in the Ribb Reservoir fishery (Mequanent et al., 2022). Despite their commercial importance, there is no information on the biology (food and feeding habits) of this species with the interaction of the ecology of the reservoirs. Exploring such type of information in Ribb Reservoir plays a fundamental role in the sustainable use of the stock and in improving the livelihoods of newly formed fish associations around the reservoir. Therefore, the present work aimed to elucidate seasonal and ontogenetic dietary changes and the feeding habits of *L. intermedius* species in the Ribb Reservoir.

Materials and Methods

Description of the study area

Ribb Reservoir (11°59'0" N to 12°2'0" N latitude and 38°0'0" E to 38°2'59" E longitude) is an earthen rock dam with a capacity of 234 million m³ of water with a height and length of 73.5 m and

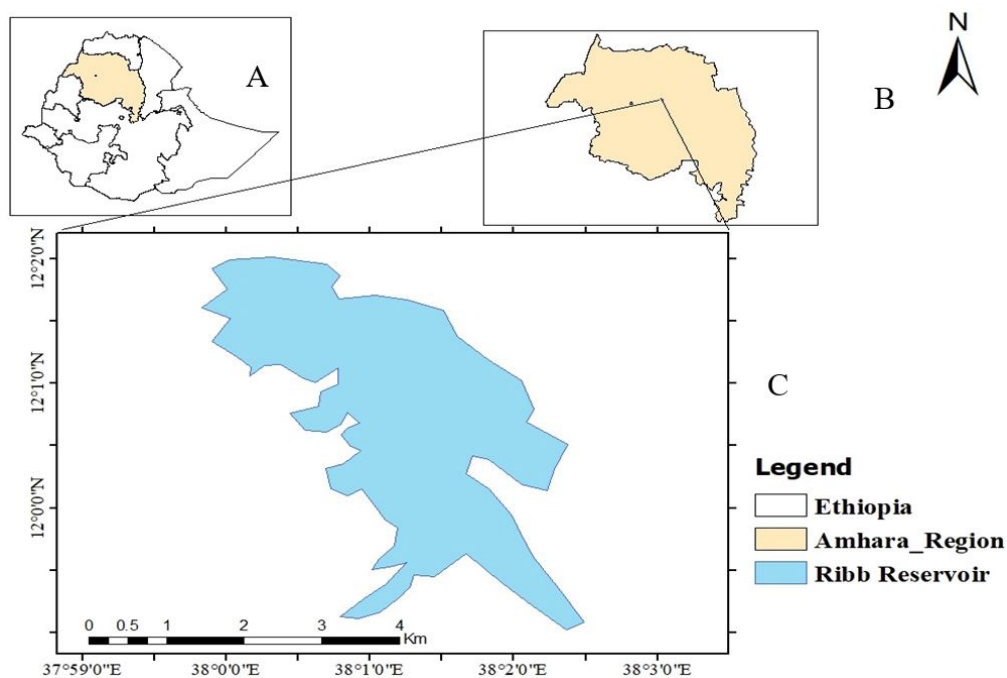


Fig. 1. Map of the study area where *Labeobarbus intermedius* specimens were collected from Ribb Reservoir, Northwest Ethiopia. Map of Ethiopia (A), Amhara region (B), and Ribb Reservoir (C).

800 m, respectively (Ministry of Water Resources of Ethiopia, 2010) (Fig. 1). The reservoir dammed on the Ribb River which is the main tributary of Lake Tana and originates at a distance of 90 km from Gunna Mountain and bounded Farta, Ebinat, Libo-Kemkem, and Fogera districts of the South Gondar Zone, Amhara Regional State (Ashenafi, 2011). The reservoir is situated mainly in the Farta district with a small part engulfing the Ebinat district of the South Gondar Zone. It is found in the Lake Tana sub-basin, in the northern part of Ethiopia and the northeastern part of the Blue Nile basin and the sub-basin has an area of 15,320 km² (Amhara Design and Supervision Works Enterprise (ADSWE), 2015). It is located at a distance of 625 km north of Addis Ababa and 60 km from Bahir Dar town, the capital city of the Amhara Regional State (Mulatu et al., 2018).

The boundary of the study area is classified as a tropical highland monsoon climate namely Wurch on Mount Gunna, Dega around Debre-Tabor town and Woina Dega near Ribb Reservoir (Ezezew, 2019). The climate of the Ribb basin was characterized by a rainy season (May to September) with 65 mm of monthly precipitation in May and 411 mm in July (Sisay, 2017). While the highest and lowest average annual rainfall of the basin were recorded as 1,400 mm and 1,200 mm, respectively (Bezabih, 2021). Whereas, there is no recorded rainfall data in the dry season. Also, the temperature of the Ribb basin varies throughout the year, from 19°C (December) to 23°C (May), and sometimes maximum temperature record of 30°C and the minimum temperature of 11.5°C (Bezabih, 2021).

Fish sampling and measurements

L. intermedius samples were collected during the wet season (June–August) and dry season (December–March) using hooks and lines, and gillnets of stretched mesh sizes of 4, 6, 8, 10, and 12 cm. Total length, fork length (FL), and standard length were measured to the nearest 0.1 cm using the measuring board. Also, the total weight (TW) was measured to the nearest 0.1 g by using a sensitive balance. Then, the fish sample was dissected with a scissor and checked for gut fullness. The non-empty guts were preserved in a 5% formaldehyde solution for further analysis.

Food and feeding habits

Identification of large foods was performed visually whereas smaller foods were identified by using a dissecting microscope (LEICA S4E, 10X/23) and compound microscope (OPTIKA E-PLAN, 10X/0.25). The relative importance of each food item to the diet of each fish species was estimated as follows.

Frequency of occurrence (%FO)

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

$$\text{Frequency of occurrence (\%FO)} = \frac{\text{Total number of guts with a particular food item}}{\text{Total number of guts with food}} \times 100$$

Volumetric analysis (%V)

Food items that are found in the guts were sorted into different taxonomic groups and the volume of each group of food items was measured (Bowen, 1983). Then, the volume of a given category of food items was expressed as a percentage of all the categories of food items present in the gut samples. For macroscopic food items, the volume of the displaced water within the measured cylinder by the food items was expressed as the volumetric percentage of the measured food item as developed by Hyslop (1980).

$$\text{Volume analysis (\%V)} = \frac{\text{Volume of one food item found in all sampled specimen}}{\text{The volume of all food items in all sampled specimens}} \times 100$$

Seasonal variation and ontogenetic dietary shift

The seasonal variations in the type of food eaten by *L. intermedius* were studied as a function of dry and wet seasons using a percentage of frequency of occurrence (%FO) and volumetric proportion. For the ontogenetic change in diet, the fish samples were determined by dividing their length into three size classes (I: < 20 cm; II: 20–29.9 cm; III: > 30 cm) (Dadebo et al., 2013). The percentage mean volume of various foods was calculated using the methods of Schoener (1970) and Wallace (1981).

Data analysis

A Chi-square (χ^2) test was used to compare the frequency of occurrences of the different food categories during dry and wet season samples (Sokal & Rohlf, 1995). Whereas, the independent sample *t*-test was used to compare the volume of the different food categories consumed during wet and dry season samples. Dietary overlap between different size classes was calculated as percentage overlap using Schoener diet overlap index (SDOI) (Schoener, 1970; Wallace, 1981):

$$\alpha = 1 - 0.5 \left(\sum_{i=1}^n |P_{ai} - P_{bi}| \right)$$

Where, α is the percentage overlap of the SDOI between size class 'a' and 'b'. P_{ai} and P_{bi} are the proportions of the food type i used by size class 'a' and 'b', and n is the total number of food types. When the α value exceeds 0.60 the diet overlap index is said to be biologically significant (Mathur, 1977).

Results

Diet composition

A total of 203 *L. intermedius* samples collected during the dry season (December to March) and wet season (June to August) were used for gut content analysis. The size of the fish samples ranged from 14.5 to 44 cm FL and weighed 56 g to 1,063 g TW. Of these, 71 (35%) were empty, while 132 (65%) contained food in the stomach. The diet of *L. intermedius* from Ribb Reservoir consists of macrophytes, phytoplankton, detritus, insects, zooplankton, nematodes, and unidentified materials. Of these foods, the most important foods were macrophytes, phytoplankton, detritus, and insects. While the remaining foods, zooplankton, nematodes, and unidentified materials, were relatively less important foods in their stomachs.

Seasonal variation

The %FO of macrophytes, phytoplankton, detritus, zooplankton, and unidentified materials in the diet of *L. intermedius* was significantly different between seasons (χ^2 test, $p < 0.05$). Similarly, the volumetric contribution of macrophytes, phytoplankton, detritus, zooplankton, and nematodes differed significantly between seasons (χ^2 test, $p < 0.05$) (Table 1). Whereas the %FO and the volumetric contribution of insects did not differ significantly between seasons. Macrophytes and detritus were the major dietary components in the diet of *L. intermedius* during the wet season, occurring in the gut at 63.5% and 71.4% in the gut and contributing 50.3% and 23.3%, respectively, to the total volume of dietary components (Table 1). During the dry season, the %FO of macrophytes (14.5%) and detritus (18.8%) was lower. Similarly, the contribution of both macrophytes (5.4%) and detritus (5%) decreased in the dry season. The volumetric contribution of phytoplankton was the first predominant food item in the diet of *L. intermedius*, occurring in 78.3% and accounting for 58.2% of the total volume of food items in the dry season. Zooplankton occurred in 23.8%

Table 1. The relative contribution of different food items in the diet of *Labeobarbus intermedius* during dry (n = 69) and wet seasons (n = 63) in Ribb Reservoir

Food items	Frequency of occurrence (%)		Volumetric contribution (%)	
	Dry season	Wet season	Dry season	Wet season
Phytoplankton	78.3 ^b	ND	58.2 ^a	ND
Green algae	33.3	ND	14.1	ND
Blue-green algae	44.9	ND	19.4	ND
Diatoms	53.6	ND	23.9	ND
Euglenoids	4.3	ND	0.8	ND
Zooplankton	55.1 ^b	23.8 ^a	13.7 ^a	4.8 ^b
Cladocera	46.4	23.8	11.0	4.8
Copepods	2.9	ND	0.6	ND
Rotifers	8.7	ND	2.1	ND
Insects	56.5 ^a	58.7 ^a	15.2 ^a	12.2 ^a
Ephemeroptera	20.3	31.7	3.3	2.6
Hemiptera	15.9	23.8	1.9	1.6
Plecoptera	11.6	0.0	3.3	0.0
Diptera	36.2	46	6.7	8
Macrophytes	14.5 ^b	63.5 ^a	5.4 ^a	50.3 ^b
Detritus	18.8 ^b	71.4 ^a	5.0 ^a	23.3 ^b
Nematodes	30.4 ^b	41.3 ^a	2.4 ^a	8.9 ^b
Unidentified materials	1.4 ^b	7.9 ^a	0.1 ^a	0.5 ^b

^{a,b} Values of respective food items under the same category given different superscript letters are significantly different (χ^2 , $\alpha < 0.05$).
ND, not detected.

and accounted for 4.8% of the total amount of food in the wet season. During the dry season, the abundance of zooplankton increased to 55.1% and contributed 13.7% to the total volume of food.

The %FO and volumetric contribution of insects in the dry and wet seasons did not vary significantly, occurring 56.5% in the dry and 58.7% in the wet season. And contributed to 15.2% and 12.2% in the dry and wet seasons, respectively (Table 1). From the insect groups, Diptera were the most predominant taxa compared to the other taxa, contributing 8% in the wet season and 6.7% in the dry season.

Ontogenetic dietary shift

SDOI revealed a significant dietary variation between I & II (0.45) and I & III (0.30) size classes but not II & III (0.69) size classes (Table 2).

In the smallest size class < 20 cm FL, the mean percentage volume of food was dominated by insects (35.5%), nematodes

Table 2. SDOI in three size classes of *Labeobarbus intermedius* from Ribb Reservoir

Size classes	SDOI value
Lower (< 20 cm TL) and intermediate (20–30 cm TL)	0.45*
Intermediate (20–30 cm TL) and higher (> 30 cm TL)	0.69
Lower (< 20 cm TL) and higher (> 30 cm TL)	0.30*

*significant diet variation ($p < 0.05$).

SDOI, Schoener diet overlap index; TL, total length.

(18.9%), zooplankton (18.6%) and detritus (12.6%). In contrast, the contribution of other foods such as phytoplankton (7.7%), macrophytes (5.7%) and unidentified materials (1.0%) was relatively small (Fig. 2).

In the intermediate size class (20–30 cm FL), the volumetric contribution of phytoplankton (42.7%), macrophytes (24.3%) and detritus (13.7%) were higher than those of insects (9.4%), zooplankton (8.5%) and nematode (1.4%) (Fig. 2). In the higher size class > 30 cm FL, the importance of macrophytes and detritus further increased to 51.1% and 17.4%, respectively. On the other hand, the importance of zooplankton, insect, nematodes, and unidentified materials was almost negligible (Fig. 2).

Discussion

The present study demonstrated that *L. intermedius* fed on macrophytes, phytoplankton, detritus, insects, zooplankton,

nematodes and unidentified materials in Ribb Reservoir. Of these foods, the first four accounted for the majority of foods (85%). While the remaining three made up 15% and are less important in the diet of *L. intermedius* (Table 3). Similar diet composition has been reported by different authors in different bodies of water such as Lake Tana (de Graaf et al., 2000; Engdaw, 2014); Lake Koka (Dadebo et al., 2013) and Tekeze Reservoir (Gebru, 2020). However, snails and fish scales have been reported in these waters, but not in the present study. In contrast to the present study results, the main food items of *L. intermedius* are mollusks (90%), fish prey and aquatic insects in Lake Awassa (Desta et al., 2006).

The most important foods in the diet of *L. intermedius* were insects, occurring in 57.6% of the intestines and 13.6% of the volumetric contributions. Among insect groups, Diptera was strongly dominant compared to other groups, its volumetric components were 7.4% (Table 3). This may be due to the dense stand of aquatic weeds supporting significant biofilm accumulation of benthic prey production as noted by Piet (1998). This finding is also consistent with Dadebo et al. (2013) in Lake Koka.

The contribution of food consumed by *L. intermedius* depends on the season, prey availability, habitat type and fish size (Desta et al., 2006). The African and Asian inland waters also showed that *L. intermedius* was polyphagous and can change its diet depending on seasonal and spatial differences in prey (Sibbing & Nagelkerke, 2000). Seasonal variations have a

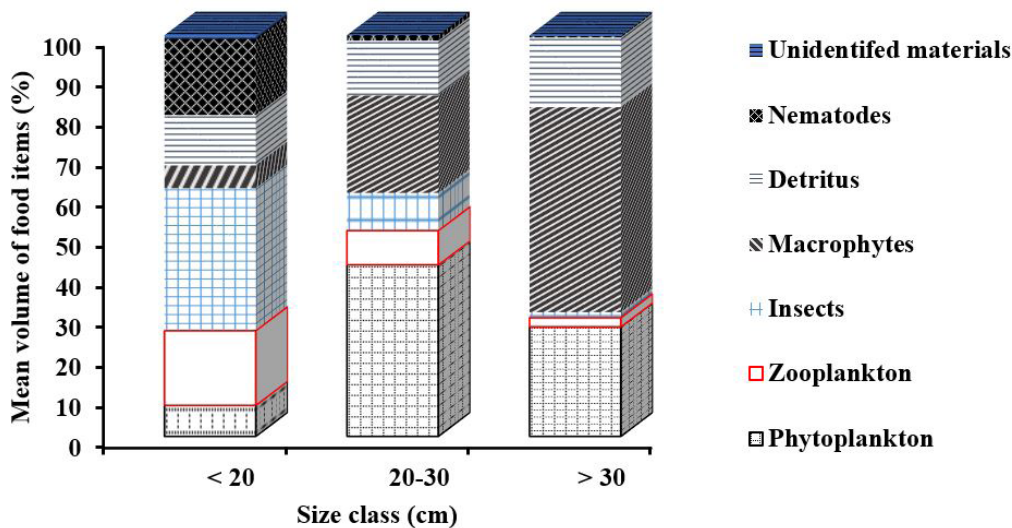


Fig. 2. The relative volume of food items consumed by different size classes of *Labeobarbus intermedius* from Ribb Reservoir.

Table 3. Frequency of occurrence and volumetric contribution of different food items in the diet of *Labeobarbus intermedius* sampled from Ribb Reservoir (n = 132)

Food items	Frequency of occurrence		Volumetric contribution	
	Number	(%)	Volume (mL)	(%)
Phytoplankton	54	40.9	124.64	27.2
Green algae	23	17.4	30.14	6.6
Blue-green algae	31	23.5	41.6	9.1
Diatoms	37	28.0	51.2	11.1
Euglenoids	3	2.3	1.7	0.4
Zooplankton	53	40.2	40.99	8.9
Cladocera	47	35.6	35.19	7.6
Copepods	2	1.5	1.25	0.3
Rotifers	6	4.5	4.55	1.0
Insects	76	57.6	62.32	13.6
Ephemeroptera	34	25.8	13.5	2.9
Hemiptera	26	19.7	8	1.8
Plecoptera	8	6.1	7.05	1.5
Diptera	53	40.2	33.77	7.4
Macrophytes	50	37.9	134.75	29.4
Detritus	58	43.9	67.9	14.8
Nematodes	47	35.6	26.85	5.8
Unidentified materials	6	4.5	1.55	0.3

The volume of the major food items adds up to 100% in volumetric analysis.

major impact on food availability and emergence (Desta et al., 2006). This is also underpinned by the current study result on the Ribb Reservoir. The feeding habits of *L. intermedius* in the present study are consistent with the omnivorous nature of *L. intermedius* studied elsewhere in the Gilgel-Gibe Reservoir in the OmoTurkana basin (Wakijira, 2013).

In the present study, *L. intermedius* showed significant seasonal variation in their feeding activity in Ribb Reservoir. This may be due to seasonal variations and the abundance of food in the reservoir. *L. intermedius* consumed phytoplankton mainly in the dry season and was almost absent in the wet season (Dadebo et al., 2013). This could be due to the high succession ability of phytoplankton during the dry season and the turbidity behavior of the reservoir in the rainy season (Dadebo et al., 2014; Wondie et al., 2007). In turbid waters, phytoplankton abundance decreased due to reduced light and low photosynthetic activity. All inflowing tributaries of the Ribb Reservoir bring a lot of sediment from the degraded catchment areas, resulting in turbid water in the reservoir, especially at the estuaries of the Ribb, Melo, Hamus Wonz and other rivers. Similar reports have been

made in different water bodies of Ethiopia such as Lake Chamo (Fekadu & Chanie, 2017). In addition, Wondie et al. (2007) also reported that phytoplankton biomass decreased during the rainy season as a result of the increased turbidity of Lake Tana.

During the wet season, macrophytes and detritus were the most important food items in the diet of *L. intermedius*, this result agrees with the study of Wakijira (2013) in Gilgel Gibe Reservoir and Dadebo et al. (2013) in Lake Koka. It was reported that macrophytes and detritus are the most important food items during the wet season and the source of the detritus is likely to be the floods that brought fragments of plant matter (Dadebo et al., 2013, 2014). In this study, the contribution of insects to the diet of *L. intermedius* was comparable in both the dry and wet seasons. However, some taxa contributions varied in both the dry and wet seasons. In general, seasonality affects the feeding behavior and prey organism species of *L. intermedius* in the Ribb Reservoir. During the rainy season, the contribution of foods of plant origin was higher than the contribution of foods of animal origin.

The SDOI rule is evident that *L. intermedius* showed a slight ontogenetic dietary shift in the Ribb Reservoir. There was a significant ontogenetic dietary shift between size classes I and II (= 0.45) and between size classes I and III (= 0.30). However, there is no significant ontogenetic dietary shift between size classes II and III (= 0.69). These non-significant results between these size classes of fish could be due to the development of similar morphological and physiological traits and the feeding of similar foods. This is because the ontogenetic dietary transition in fish is determined by the morphological and physiological characteristics of the fish (Agembe et al., 2019).

The diet composition of *L. intermedius* showed that the foods in each size class were digested, but at different rates. For example, insects, zooplankton, and nematodes have been heavily included in smaller size classes, but decreased with the size of the fish. On the other hand, the uptake rate of macrophytes and detritus increased with the size of the fish. This size-dependent dietary change may be due to the morphological and physiological development, water type, and habitat of the fish (Engdaw et al., 2013). Most juveniles prefer to swim in the coastal region, feeding on the invertebrate molluscs and zooplankton that are prevalent there (Dadebo, 2009). As they grow in size, they swim in open water and feed on large dietary components of macrophytes, detritus, and others related to the morphology and physiological traits of the fish.

In this study, the composition of insects and macrophytes

(the most important foods) showed significant differences in different size classes. For example, insects were consumed heavily in smaller classes but less in larger classes. Whereas macrophytes were heavily consumed by the larger size class, while consumed less in the lower size class. This study result agrees with the work of Desta et al. (2006) in Lake Hawassa, who found a slight ontogenetic dietary change. They found that insects are the most important food elements for juvenile fish, but their importance decreases with the size of the fish and shifts to piscivorous diets with increasing size, but not the fish prey observed in the current investigation. Furthermore, it has been reported that slight ontogenetic variation is observed in Lake Koka, where macrophytes are dominant foods in the higher-size class but are relatively less important in the smaller-size class diet (Dadebo et al., 2013). In this study, insects were the dominant foods in the smaller size class, but relatively less important in the larger size class.

In conclusion, this study has demonstrated the diet, seasonal variations, and ontogenetic dietary shifts of *L. intermedius* in the Ribb Reservoir. The main components of the diet were macrophytes, phytoplankton, detritus and insects. While the rest of the foods in his diet were less important. The present study also showed seasonal variations and dietary changes in the size of the fish. In the dry season, zooplankton and phytoplankton were the main diets, while in the wet season, macrophytes and detritus were the predominant diets. The SDOI rule shows that there was significant diet variation of size class I compared to size classes II and III of *L. intermedius* and a slight ontogenetic dietary shift ensued. However, size classes II and III did not show any significant change in diet.

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 of this study can be 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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References

- Adeyemi SO, Bankole NO, Adikwu IA, Akombu PM. Food and feeding habits of some commercially important fish species in Gbedikere Lake, Bassa, Kogi State, Nigeria. *Int J Lakes Rivers*. 2009;2:31-6.
- Agembe S, Yongo E, Masese F, Njiru J, Manyala J, Ojwang W. Shifts in the food of Nile perch (*Lates niloticus*) in Lake Victoria. *Lakes Reserv Sci Policy Res Manag Sustain Use*. 2019;24:13-7.
- Amhara Design and Supervision Works Enterprise [ADSWE]. Tana sub-basin land use planning and environmental study project: hydrology and water resource assessment. Bahir Dar: Bureau of Environmental Protection, Land Administration and Use; 2014. Report No.: ADSWE, LUPESP/TaSB: sII, vIII/2014.
- Ashenafi S. Evaluation of the implementation of environmental impact assessment in dam projects: the case of Ribb and Dire dams [M.S. thesis]. Addis Ababa: Addis Ababa University; 2011.
- Awoke T. Fish species diversity in major river basins of Ethiopia. *World J Fish Mar Sci*. 2015;7:365-74.
- Bagenal TB, Braum E. Eggs and early life history. In: Bagenal TB, editor. *Methods for assessment of fish production in fresh waters*. London: Blackwell Scientific; 1978. p. 165-201.
- Bezabih AW. Evaluation of small hydropower plant at Ribb irrigation dam in Amhara regional state, Ethiopia. *Environ Syst Res*. 2021;10:1.
- Bowen SH. Quantitative description of the diet. In: Nielsen LA, Johnson DL, editors. *Fisheries techniques*. Bethesda, MD: American Fisheries Society; 1983. p. 325-36.
- Dadebo E. Filter-feeding habit of the African catfish *Clarias*

- gariiepinus* Burchell, 1822 (Pisces: Clariidae) in Lake Chamo, Ethiopia. *Ethiop J Biol Sci.* 2009;8:15-30.
- Dadebo E, Aemro D, Tekle-Giorgis Y. Food and feeding habits of the African catfish *Clarias gariepinus* (Burchell, 1822) (Pisces: Clariidae) in Lake Koka, Ethiopia. *Afr J Ecol.* 2014;52:471-8.
- Dadebo E, Tesfahun A, Teklegiorgis Y. Food and feeding habits of the African big barb *Labeobarbus intermedius* (Rüppell, 1836) (Pisces: Cyprinidae) in Lake Koka, Ethiopia. *E3 J Agric Res Dev.* 2013;3:49-58.
- de Graaf M, Dejen E, Sibbing FA, Osse JWM. The piscivorous barbs of Lake Tana (Ethiopia): major questions on their evolution and exploitation. *Neth J Zool.* 2000;50:215-24.
- Dejen E, Anteneh W, Vijverberg J. The decline of the Lake Tana (Ethiopia) fisheries: causes and possible solutions. *Land Degrad Dev.* 2017;28:1842-51.
- Deribe E, Rosseland BO, Borgström R, Salbu B, Gebremariam Z, Dadebo E, et al. Bioaccumulation of persistent organic pollutants (POPs) in fish species from Lake Koka, Ethiopia: the influence of lipid content and trophic position. *Sci Total Environ.* 2011;410-411:136-45.
- Desta Z, Borgström R, Rosseland BO, Gebre-Mariam Z. Major difference in mercury concentrations of the African big barb, *Barbus intermedius* (R.) due to shifts in trophic position. *Ecol Freshw Fish.* 2006;15:532-43.
- Engdaw F. Morphometric relations, diet composition and ontogenetic dietary shift of *Labeobarbus intermedius* (Rüppell, 1836) in Lake Tana gulf of Gorgora, Ethiopia. *Int J Fish Aquac.* 2014;6:124-32.
- Engdaw F, Dadebo E, Nagappan R. Morphometric relationships and feeding habits of Nile Tilapia *Oreochromis niloticus* (L.) (Pisces: Cichlidae) from Lake Koka, Ethiopia. *Int J Fish Aquat.* 2013;4:65-71.
- Ezewew G. Estimation of Ribb dam catchment sediment yield and reservoir effective life using SWAT model and empirical methods [M.S. thesis]. Bahir Dar: Bahir Dar University; 2019.
- Fekadu A, Chanie S. A seasonal study on phytoplankton diversity and dynamics of Lake Chamo, Ethiopia. *Aquat Living Resour.* 2017;30:1-9.
- Gebremedhin S, Bruneel S, Getahun A, Anteneh W, Goethals P. The endemic species flock of *Labeobarbus* spp. in L. Tana (Ethiopia) threatened by extinction: implications for conservation management. *Water.* 2019;11:2560.
- Gebru S. Fish diversity and production in Tekeze Reservoir, Tekeze basin, Ethiopia [Ph.D. dissertation]. Ethiopia: Addis Ababa University; 2020.
- Hyslop EJ. Stomach contents analysis: a review of methods and their application. *J Fish Biol.* 1980;17:411-29.
- Mathur D. Food habits and competitive relationships of the bandfin shiner in Halawakee Creek, Alabama. *Am Midl Nat.* 1977;97:89-100.
- Mequanent D, Mingist M, Getahun G, Anteneh W, Hailu B. The newly built Ribb Reservoir fisheries, Tana sub-basin, Ethiopia: new fishery establishment, diversity, production, challenges and management. *Aquac Fish Fish.* 2022;2:189-201.
- Mingist M, Gebremedhin S. Could sand mining be a major threat for the declining endemic *Labeobarbus* species of Lake Tana, Ethiopia? *Singap J Trop Geogr.* 2016;37:195-208.
- Ministry of Water Resources of Ethiopia. Environmental and social impact assessment of about 20,000 ha irrigation and drainage schemes at Megech pump (Seraba), Ribb and Anger dam: Environmental and Social Impact Assessment of the Megech Pump (Seraba) Irrigation and Drainage Project. Addis Ababa: Metaferia Consulting Engineers; 2010.
- Mulatu CA, Crosato A, Moges MM, Langendoen EJ, McClain M. Morphodynamic trends of the Ribb river, Ethiopia, prior to dam construction. *Geosciences.* 2018;8:255.
- Otieno ON, Kitaka N, Njiru JM. Length-weight relationship, condition factor, length at first maturity and sex ratio of Nile tilapia, *Oreochromis niloticus* in Lake Naivasha, Kenya. *Int J Fish Aquat Stud.* 2014;2:67-72.
- Piet GJ. Impact of environmental perturbation on a tropical fish community. *Can J Fish Aquat Sci.* 1998;55:1842-53.
- Schoener TW. Nonsynchronous spatial overlap of lizards in patchy habitats. *Ecology.* 1970;51:408-18.
- Shalloof K, El-Kasheif M, Authman M. Food and feeding habits of three cichlid species inhabiting Damietta branch of the river Nile, Egypt. *Egypt J Aquat Biol Fish.* 2009;13:49-66.
- Shalloof KAS, Khalifa N. Stomach contents and feeding habits of *Oreochromis niloticus* (L.) from Abu-Zabal lakes, Egypt. *World Appl Sci J.* 2009;6:1-5.
- Sibbing FA, Nagelkerke LAJ. Resource partitioning by Lake Tana barbs predicted from fish morphometrics and prey characteristics. *Rev Fish Biol Fish.* 2000;10:393-437.
- Sibbing FA, Nagelkerke LAJ, Osse JWM. Ecomorphology as a tool in fisheries: identification and ecotyping of Lake Tana barbs (*Barbus intermedius* complex), Ethiopia. *Neth J Agric*

Sci. 1994;42:77-85.

- Sisay R. Developing reservoir operation rule and assessing hydropower options under climate change on Ribb irrigation dam [M.S. thesis]. Arba Minch: Arba Minch University; 2017.
- Sokal RR, Rohlf FJ. Biometry: the principles and practices of statistics in biological research. 3rd ed. New York, NY: W. H. Freeman; 1995.
- Vijverberg J, Dejen E, Getahun A, Nagelkerke LAJ. The composition of fish communities of nine Ethiopian lakes along a North-South gradient: threats and possible solutions. *Anim Biol.* 2012;62:315-35.
- Wakijira M. Feeding habits and some biological aspects of fish species in Gilgel Gibe Reservoir, Omo-Turkana basin Ethiopia. *Int J Curr Res.* 2013;5:4124-32.
- Wallace RK Jr. An assessment of diet-overlap indexes. *Trans Am Fish Soc.* 1981;110:72-6.
- Wondie A, Mengistu S, Vijverberg J, Dejen E. Seasonal variation in primary production of a large high altitude tropical lake (Lake Tana, Ethiopia): effects of nutrient availability and water transparency. *Aquat Ecol.* 2007;41:195-207.