East African Journal of Biophysical and Computational Sciences

ISSN (Online): 2789-3618 and ISSN (Print): 2789-360X

ARTICLE

Feeding Habits and Trace Metal Concentrations in Organs of the Nile Catfish, *Synodontis schall* (Bloch & Schneider) (Pisces: Mochokidae), in Lake Abaya, Ethiopia

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ARTICLE INFO
Volume 7(1), 2026
https://dx.doi.org/10.4314/eajbcs.v7i1.4S

ARTICLE HISTORY
Received: 14 April, 2026
Accepted: 26 May, 2026
Published Online: 10 June, 2026

CITATION
Dadebo et.al (2026). Feeding Habits and Trace Metal Concentrations in Organs of the Nile Catfish, *Synodontis schall* (Bloch & Schneider) (Pisces: Mochokidae), in Lake Abaya, Ethiopia . *East African Journal of Biophysical and Computational Sciences* Volume 7(1), 2026. .https://dx.doi.org/10.4314/eajbcs.v7i1.4S.34-42

Abstract

This study investigated the feeding habits and trace metal concentrations in different organs of the Nile catfish, *Synodontis schall*, in Lake Abaya, Ethiopia. Stomach content analysis was conducted using frequency of occurrence and volumetric analysis. The results of the study indicated that *S. schall* is an omnivore with polyphagous feeding habits; dominant food categories included phytoplankton, detritus, insects, zooplankton, and macrophytes. Seasonal shifts were observed: phytoplankton was the primary food source during the dry season, whereas zooplankton predominated during the wet season. Ontogenetic dietary shifts were also noted with juveniles consuming mainly phytoplankton and zooplankton, while adults mainly fed insects, detritus and phytoplankton. Trace metal analysis identified copper (Cu), cadmium (Cd), nickel (Ni), zinc (Zn), and manganese (Mn) in liver, kidney and muscle tissues, while lead (Pb) and cobalt (Co) were not detected. Metal concentrations in the liver were ranked as Cu > Zn > Mn > Ni > Cd, while in muscle and kidney tissues, the order was Zn > Cu > Mn > Ni > Cd. Significant difference ($p < 0.05$) in mean concentrations of Cu, Cd, and Zn were noted among tissues. All detected heavy metals were within the FAO and EU safety limits, suggesting that *S. schall* from Lake Abaya is safe for human consumption.

Keywords: Feeding habits; Lake Abaya; Omnivory; *S. schall*; Trace metals

1 Introduction

The genus Synodontis is widely distributed across African freshwaters ranging from the Nile basin, Chad, Niger, and much of the West African region (Paugy et al., 2003) (Cuvier, 1816,). In Ethiopia, the Nile catfish *Synodontis schall* (Bloch and Schneider, 1801) is found in Lakes Abaya and Chamo in the south, the Baro River and its tributaries in the west, and in the Wabishebele River in the southeast (Golubtsov & Habteselassie, 2010; Golubtsov et al., 1995). Generally, *S. schall* is classified as an omnivore and benthic fish species, and its diet covers a wide spectrum of food ranging from plankton to invertebrates and plants (Laléyè et al., 2006). This dietary flexibility, combined with a high tolerance for adverse environmental conditions, allows the species to remain abundant in most African fresh waters (Lowe-Mcconnell, 1987).

In Lake Abaya, *S. schall* is abundant in both littoral and pelagic environments, likely due to low predation and minimal fishing pressure (Dadebo et al., 2012) . While the species is among the most favored edible fishes in some African countries (Lalèyè et al., 2006), it currently holds low commercial importance in Lake Abaya. Although, it remains ecologically indispensable as a primary prey species for the commercially significant catfish, *Bagrus docmac* (Forsskål, 1775) (Anja & Mengistou, 2001). Previous studies across Africa have highlighted the species' opportunistic feeding nature (Adeyemi, 2010; Akombo et al., 2014; Arame et al., 2021; Dadebo et al., 2012). Yongo et al. (2019) reviewed the feeding habits of some *Synodontis* species in African freshwaters, and reported that the genus feeds on a variety of food items, including vegetable materials, insects, mollusks, detritus, macrophytes, fish scales, and plankton. In Quémé River, the most frequent food items in the stomachs of *S. schall* were macrophytes, algae, crustaceans, rotifers, and mollusks (Lalèyè et al., 2006). Ofori-Danson (1992) reported that the frequent food items of *S. schall* in the Kpong head pond were benthic macroinvertebrates. Adeosun et al. (2017) indicated the importance of insects, rotifers, crustaceans, fish parts and phytoplankton in the diet of *S. schall*.

Beyond ecological dynamics, the health of fish populations is increasingly threatened by the accumulation of trace metals from natural and anthropogenic sources (Ali & Khan, 2018). Because fish occupy various trophic levels, they can accumulate toxic substances in vital organs and muscle tissues, posing risks not only to aquatic biota but also to human consumers through trophic transfer (Garai et al., 2021). Given the benthic feeding habits of *S. schall*, it is particularly susceptible to metals associated with lake sediments.

Despite its ecological importance, there is lack of information regarding the biology and ecology of *S. schall* in Ethiopia. To the knowledge of the researchers, there is no published data regarding the feeding habits and heavy metal load in the organs of *S. schall* specifically within Lake Abaya. Therefore, the aim of this study was to investigate the dietary patterns and concentrations of trace metals in different organs of this species. Such information is vital for future management of the fish stock for assessing the environmental health of the Lake Abaya ecosystem.

2 Materials and Methods

2.1 Study Area

Lake Abaya is the second largest lake in Ethiopia and geographically located between 5°55′9″ and 6°35′30″ N latitude, and 37°36′90″ and 38°03′45″ E longitude in the southern part of the Ethiopian Rift Valley, East of the Guge Mountains (Figure 1) (Shishitu, 2024) . The lake is fed on its northern shore by the Bilate River, which rises on the southern slope of mount Gurage (Golubtsov & Habteselassie, 2010). Other rivers that drain in to the lake include, Gelana, Milate, Gidabo, Harre, Baso, and Amesa. The only outflow of the lake is through the lower reaches of Kulfo River directly below an alluvial pan at an elevation of 1,190 m. Arba Minch town lies on its southwestern shore and the southern shores are part of the Nechisar National Park (Teffera et al., 2019). Lake Abaya has a length of 79 km, a width of 29 km, and a surface area of 1,160 km2 (Baxter, 2002). It has a maximum depth of 13 m and is located at an elevation of 1,268 m (Baxter, 2002; Grove et al., 1975). Lake Abaya is a home to 21 different fish species that have economic and ecological roles (Golubtsov & Habteselassie, 2010).

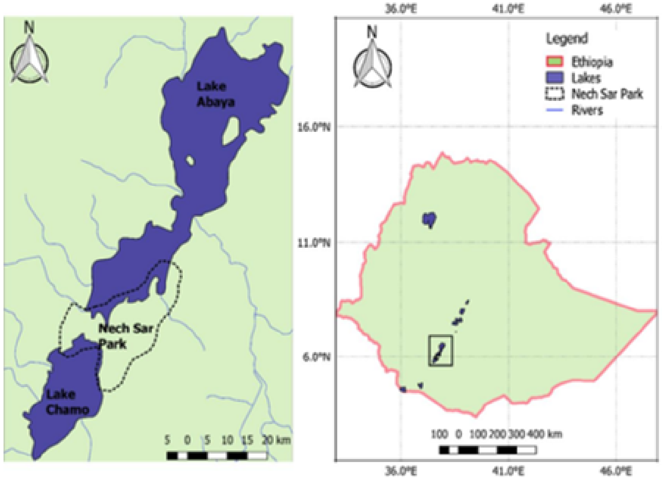

Figure 1: Geographic location of Lake Abaya (Source: adopted from Shishitu, 2024)

2.2 Sampling and Measurements

A total of 849 *S. schall* specimens were collected during the dry season (January to February, 2020) and the wet season (June to July, 2020) (wet season). Sampling was conducted at both littoral and pelagic sites of the lake using a beach seine (25 m long and three meters wide with a mesh size of 0.6 cm) in the shallow littoral area and Nordic survey multi-mesh monofilament nylon gillnets (Appelberg et al., 1995) at the pelagic area of the lake.

The multi-mesh gillnets consisted of twelve randomly distributed panels of the mesh sizes 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 25, 29, 35, 43, and 53 mm (bar mesh). Each panel was 2.5 m long, and hence the total length of each net was 30 m. The gillnets were set between three to five meters depths in the open water, about 1.5 km inward from the littoral sampling station. The gillnets were set early in the morning around 7.00 a.m. local time and pulled around 3.00 p.m. in the afternoon.

For each specimen, fork lengths (FL) and standard length (SL) were measured to the nearest mm using a measuring board. Total weight (TW) was measured to the nearest 0.1g using a SCALTEC digital balance (model 23565, USA). The stomach of each fish was split open, and the contents were collected and preserved in 5% formalin solution and transported to Hawassa University Fishery Laboratory for further analysis.

2.3 Stomach Content Analysis

The stomach contents of each specimen were examined visually to identify macroscopic food items, whereas a dissecting microscope (Leica, MS5, magnification- 40x) and a compound microscope (Leica DME, magnification- 1000x) were used to identify microscopic food items. Quantitative analysis of the diet was conducted using frequency of occurrence and volumetric methods of analyses.

Frequency of occurrence (%FO): the number of stomach samples containing one or more individuals of each food category was expressed as a percentage of all stomachs containing food (Hyslop, 1980). In volumetric analysis (%V), the food items found in each stomach were sorted into different food categories, and the water displaced by the group of volume of items in each category was measured (Bowen, 1996). The relative importance of each category was then expressed as a percentage of the total volume of food categories.

2.4 Ontogenetic Dietary Shift and Dietary Overlap

To assess ontogenetic dietary shifts, specimens were categorized into five size classes (Class I: 5- 9.9 cm; Class II: 10-14.9 cm; Class III: 15-19.9 cm; Class IV: 20-24.9 cm; Class V: 25- 29.9 cm). The total volume of food items in each size class was determined and volumetric contribution of each category of food items was then expressed as a percentage of total volume of food consumed in each size class. The dietary overlap between different size-classes was calculated as percentage overlap using the Schoener Diet Overlap Index (SDOI) (Schoener, 1970; Wallace Jr, 1981) based on Eq.(1) :

$$\alpha = 100[l - 0.5]\left(\overset{n}{\underset{i=1}{}}|P_{xi} - P_{yi}|\right) \tag{1}$$

where α is percentage overlap SDOI, between size group x and y, Pxi and Pyi are proportions of food category (type) i used by size group x and y, and n is the total number of food categories. Diet overlap in the index is generally considered to be strong dietary similarity and overlap when α value exceeds 0.60 (Mathur, 1977; Zaret & Rand, 1971).

2.5 Fish Samples Collection and Preservation for Determination of Heavy Metals

A total of 20 *S. schall* specimens were collected from Lake Abaya for heavy metal analysis using gill nets and a beach seine. For each specimen, fork length (FL) and total weight (TW) of each fish were recorded to the nearest 0.1 cm and 0.1 g, respectively. Fish dissection for muscle, kidney, and liver samples followed the EMERGE protocol, ensuring proper handling (Gupta & Mullins, 2010). The separated organs and muscles were quickly wrapped in aluminum foil and then placed in plastic bags. These bags were subsequently stored in an icebox and transported to the deep freezer at Hawassa University Laboratory. Finally, the samples were preserved at a temperature of -20 °C in the deep freeze.

2.6 Sample Preparation for Atomic Absorption Spectroscopy (AAS) Analysis

Muscle, liver, and kidney tissues were mechanically crushed with a stainless steel knife and partially air-dried overnight. They were then fully dried in a laboratory oven at 175°C for three hours and processed separately except for Pb and Cd. For Pb and Cd 60°C were considered. A solution of aqua regia (3:1 hydrochloric to nitric acid) was prepared as per Nwani et al. (2010). One gram of dried muscle and 0.5 grams of liver and kidney were added to a 100 ml flask with 10 ml of aqua regia and refluxed overnight to dissolve organic materials and release trace metals, following Muinde et al. (2013) method. After refluxing, samples were digested at 60°C for three hours to enhance reaction kinetics. Each sample was digested in triplicates and diluted to a final volume in a 50 ml volumetric flask and filtered with the attached monochromater filter.

2.7 Determination of Heavy Metals

The digested fish organ and muscle were analyzed for Cd, Co, Cu, Mn, Ni, Pb, and Zn using flame atomic absorption spectrometry (FAAS) with a dual background correction system (BUCK SCIENTIFIC, Model 210VGP, USA). An air-acetylene flame was employed, utilizing aqueous calibration standards from stock solutions of the metals. Three standard solutions and a blank solution, made from the acid used in digestion, were prepared to minimize errors and avoid overestimating heavy metal concentrations due to contamination. The trace metal concentrations in the organs were calculated by subtracting the levels in the stock solution from those measured in the acid. Each sample was aspirated into the FAAS for direct readings, and the blank was created by combining all reagents in a 50 ml volumetric flask and diluting with deionized water. Finally, the FAAS was adjusted with the following detection limit capacity of the element as Cd (0.03 mg/kg), Co (0.02 mg/kg), Cu (0.005 mg/kg), Mn (0.03 mg/kg), Ni (0.02 mg/kg), Pb (0.03 mg/kg), and Zn (0.005 mg/kg), respectively.

2.8 Statistical Analysis

The chi-square test was employed to compare the variations of the frequency of occurrence of the different food categories during the dry and wet seasons (Worms and Touati, 2017). For volumetric data, the Mann-Whitney U test was used to assess seasonal differences (Worms & Touati, 2017). This non-parametric test was used because the data violated the assumption of homogeneity of variance required for parametric test. For the comparisons of ontogenetic dietary overlap between different size classes, their schooner dietary overlap index was considered depending on the benchmark (0.6). The concentration of considered trace metals from the muscle, kidney, and liver of *S. schall* was compared using one-way analysis of variance with the aid of SPSS v20 software at a 95% confidence interval.

3 Results

3.1 Diet Composition

From a total of 849 *S. schall* specimens examined, 751 (88.5%) contained food, while 98 (11.5%) had empty stomachs. The sampled fish ranged in size from 5.4 to 33.0 cm in fork length and weighed between 2.6 and 566 g in total weight. The diet of *S. schall* in Lake Abaya was diverse, consisting of phytoplankton, zooplankton, insects, macrophytes, detritus, ostracods, nematodes, hydracarina and fish scales at different proportion (Table 1). Of these, the frequency of occurrences of detritus, insects, macrophytes, zooplankton and phytoplankton were identified as major food categories, while ostracods, nematodes, fish scales and Hydracarina were found to be of minor importance (Table 1). Volumetrically, the contributions of Phytoplankton (31.20%), detritus (20.10%), insects (16.80%), zooplankton (13.40%) and macrophyte (12.80%) were dominant as a diet of *S. schall*. While, the volumetric contributions of other identified food categories were negligible (Table 1).

Table 1: Diet Compositions of *S. schall* (n = 751) in Lake Abaya, Ethiopia

	Frequency of occurrences		**Volumetric contribution**	
Food type	**FO**	**%FO**	**VC(ML)**	**%VC**
Phytoplankton	**352**	**46.90**	**154.70**	**31.20**
Blue green algae	236	31.40	87.23	17.60
Green algae	57	7.60	8.72	1.80
Diatoms	133	170	58.51	11.80
Euglinoids	3	0.40	0.20	0.04
Zooplankton	**411**	**54.70**	**66.42**	**13.40**
Cladocera	343	45.70	58.35	11.80
Calanoid copepods	87	11.60	6.11	1.20
Cyclopoid copepods	35	4.70	1.76	0.40
Rotifera	5	0.70	0.19	0.04
Insects	**484**	**64.40**	**83.24**	**16.80**
Diptera	354	47.10	50.90	10.30
Ephemeroptera	101	13.40	8.70	1.80
Plecoptera	80	10.70	12.01	2.40
Coleoptera	59	7.90	4.35	0.90
Hymenoptera	23	3.10	1.32	0.30
Tricoptera	8	1.10	1.52	0.30
Anisoptera	7	0.90	4.12	0.80
Hemiptera	8	1.10	0.12	0.02
Macrophytes	**431**	**57.40**	**63.54**	**12.80**
Detritus	**490**	**65.20**	**99.77**	**20.10**
Ostracods	**203**	**27.00**	**22.26**	**4.50**
Hydracarina	**10**	**1.30**	**0.23**	**0.05**
Nematodes	**93**	**12.40**	**3.38**	**0.68**
Fish scales	**14**	**1.90**	**3.02**	**0.60**

3.2 Seasonal Variation in the Diet Composition

Significant seasonal variations were observed in the diet of *S. schall* in Lake Abaya (Table 2). The frequency of occurrence of phytoplankton and zooplankton significantly varied during the dry (64.80%) and wet (29.30%) seasons (x^2 test, p < 0.05; Table 2). The occurrences of insects (68.8%), phytoplanktons (64.8%), detritus (62.20%), and macrophytes (53.3%) were the major food items of *S. schall* during dry season. While, during wet season, the occurrences of zooplanktons (70.50%), detritus (68.20%), and macrophytes (58.80%) were the three most ingested food items of *S. schall*. The remaining food categories in both dry and wet seasons were negligible (Table 2). Volumetrically, during dry season the contribution of phytoplankton (41.20%), detritus (19.60%), insects (17.40%), and macrophytes (13.10%) were the major food categories of *S. schall*. On the other hand, during wet season, zooplankton (26.40%), detritus (21.00%), phytoplanktons (18.33%) were the dominant food categories of *S. schall*. The contributions of other food categories were relatively low (Table 2).

Table 2: Diet Compositions of *S. schall* during the Dry (n = 304) and Wet (n = 447) Seasons in Lake Abaya.

	Frequency of occurrence (%)		**Volumetric contribution (%)**	
Food items	**Dry**	**Wet**	**Dry**	**Wet**
Phytoplankton	**64.80**	**29.30**	**41.20**	**18.33**
Blue green algae	48.40	12.80	28.60	3.60
Green algae	13.20	3.10	2.80	0.40
Diatoms	17.80	18.30	9.80	14.30
Euglinoids	-	-	-	-
Zooplankton	**28.60**	**70.50**	**3.00**	**26.40**
Cladocera	10.50	69.60	0.80	25.40
Copepoda	22.40	7.60	2.20	0.90
Rotifera	-	0.90	-	0.20
Insects	**68.80**	**59.50**	**17.41**	**15.94**
Diptera	61.50	37.40	13.00	6.80
Ephemeroptera	10.90	15.40	1.70	2.80
Plecoptera	2.30	15.90	0.50	3.80
Coleoptera	3.00	11.20	0.30	1.70
Hymenoptera	5.90	1.10	0.40	0.10
Tricoptera	-	1.10	-	0.70
Anisoptera	2.30	-	1.50	-
Hemiptera	0.70	0.90	0.010	0.040
Macrophytes	**53.60**	**58.80**	**13.10**	**12.5**
Detritus	**62.20**	**68.20**	**19.60**	**21.00**
Ostracods	**203**	**25.50**	**4.60**	**4.30**
Hydracarina	**-**	**2.20**	**-**	**0.05**
Nematodes	**4.30**	**17.90**	**0.10**	**0.580**
Fish scales	**3.00**	**1.10**	**1.00**	**0.90**

3.3 Ontogenetic Diet Shift and Dietary Overlap

The diet of *S. schall* exhibited distinct changes across the five size classes (Figure 1). *S. schall* in size class 5-9.9 cm FL widely relied on phytoplankton (60.3%) and zooplankton (17.4%) compared to the contributions of other identified food categories (Figure 1). When *S. schall* attained 10-14.9 cm FL size class, the importance of detritus, insects, macrophytes and ostracods increased while the contributions of phytoplankton and zooplankton decreased (Figure 2). As the fish grew to the 15-19.9 cm FL size range, it relied mainly on phytoplankton (30.6%), detritus (19.8%), insects (17.4%), macrophytes (12.4%) and ostracods (4.1%). When the fish further grew to 20-24.9 cm FL size range, it mainly consumed phytoplankton (25.6%), detritus (21.5%), insects (18.2%), macrophytes (11.6%) and ostracods (4.1%) (Figure 2). The major food categories of the largest size class (25-29.9 cm FL) were phytoplankton (45.5%), macrophytes (17.4%), detritus (16.5%) and insects (16.1%) by volume (Figure 2). Other food categories, namely fish scales and zooplankton had negligible role and unimportant in the diet of the largest size class.

The Schoener Diet Overlap Index (SDOI) indicated significant diet similarity (> 60%) between several size classes, with the highest overlap observed between classes III and IV (α = 93.3%) and II and III α = 81.8%). Other significant overlaps were recorded for combinations III and V (α = 79.9%), IV and V (α = 77.8%), II and V (α = 69.0%), I and IV (α α = 66.9%), and I and V (α = 65.1%) (Table 3). In contrast, diet overlap was not biologically significant for size classes I and II (α = 52.0%), I and III (α = 58.8%), and II and IV (α = 55.0%), suggesting a higher degree of dietary partitioning among these groups.

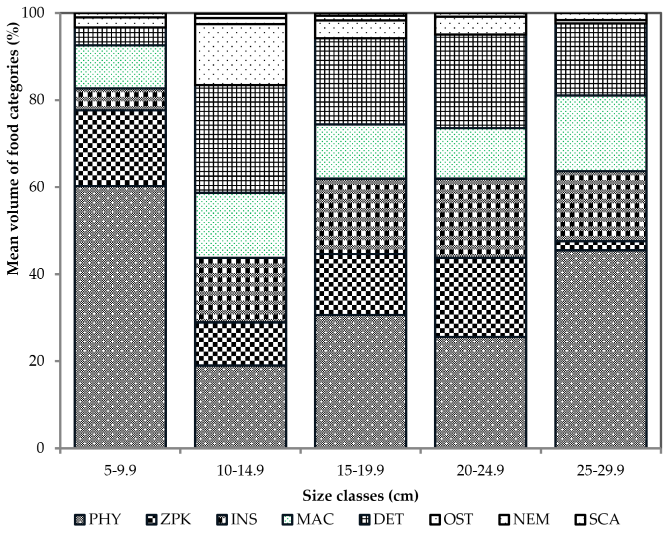

Figure 2: Mean volume of food items consumed by different size class of *S. schall* sampled from Lake Abaya.

Table 3: Schoener Diet Overlap Index (SDOI) in five size classes of *S. schall* from Lake Abaya, Ethiopia

Size class	**SDOI (%)**
I and II	52.0
I and III	58.8
I and IV	65.1*
I and V	66.9*
II and III	81.8*
II and IV	55.0
II and V	69.0*
III and IV	93.3*
III and V	79.6*
IV and V	77.8*

*indicated SDOI value showed strong dietary overlap between considered size classes

3.4 Concentration of Some Heavy Metals in Muscle, Liver and Kidney

The concentrations of seven heavy metals in liver, muscle, and kidney tissues of *S. schall* from Lake Abaya are summarized in Table 3. The findings indicated that five heavy metals - Cu, Cd, Ni, Zn, and Mn - were detected in all tissue types at levels exceeding the analytical detection limits (see the detection limit from material and method at sub section of determination of heavy metals). Conversely, Pb and Co were found at levels below the detection threshold of the equipment, as detailed in Table 4. The distribution of metals in the liver was ranked as Cu > Zn > Mn >Ni > Cd, while in the muscle and kidney tissues, the order was Zn > Cu > Mn > Ni > Cd.

Mean concentrations exhibited significant tissue specific variations (Table 3). The mean concentration of Cu was notably higher in the liver (3.847±0.341 mg/kg DW) compared to the kidney (1.211±0.168 mg/kg DW) and muscle (0.944±0.028 mg/kg DW). Similarly, Zn levels were elevated in the liver (1.85±0.153 mg/kg DW) relative to the kidney (1.38±0.179 mg/kg DW) and muscle (1.26±0.169 mg/kg DW). Conversely, more Cd concentration was detected in the kidney (0.03±0.006 mg/kg DW), followed by the liver (0.017±0.002 mg/kg DW) and muscle (0.011±0.00). The mean concentrations of Cu in muscle (0.94), kidney (1.21), and liver (3.85) exhibited significant differences ($p < 0.05$). Likewise, Cd levels in muscle (0.01), kidney (0.03), and liver (0.02) also showed significant variation ($p < 0.05$). The mean Zn concentrations in muscle (1.26), kidney (1.38), and liver (1.85) indicated significant differences ($p < 0.05$). In contrast, the concentrations of Ni and Mn did not show significant differences ($p > 0.05$) across the three tissues.

Table 4: Mean concentrations of trace metals in muscle, kidney and liver (mean concentration in mg/kg dry weight ± standard error) of *S. schall* in Lake Abaya.

Element	Muscle	Kidney	Liver
Cu	0.94 ± 0.028^{a}	1.21 ± 0.168^{a}	3.85 ± 0.341^{b}
Cd	0.01 ± 0.000^{a}	0.03 ± 0.006^{b}	0.02 ± 0.002^{a}
Ni	0.05 ± 0.006^{a}	0.05 ± 0.007^{a}	0.04 ± 0.006^{a}
Zn	1.26 ± 0.169^{a}	1.38 ± 0.179^{a}	1.85 ± 0.153^{b}
Mn	0.07 ± 0.008^{a}	0.09 ± 0.011^{a}	0.09 ± 0.009^{a}
Pb	ND	ND	ND
Co	ND	ND	ND

Note: Superscript represented by different letters indicate significant difference ($p < 0.05$), ND–Not detected.

3.5 Discussion

The results of the present study indicated that *S. schall* feeds on various food items including phytoplankton, zooplankton, insects, detritus, macrophytes, ostracods, nematodes, fish scales and Hydracarina in Lake Abaya (Table 1). From the various food items, phytoplankton, detritus, insects, zooplankton and macrophytes were the major food items while ostracods, nematodes, fish scales and Hydracarina were of minor importance. Various authors studied the feeding habits of *S. schall* and reported its polyphagous nature. Hickley and Bailey (1987) studying *S. schall* in the Sudd Swamps of River Nile (Sudan) have pointed out the importance of detritus, benthic algae, macrophytes, benthic crustaceans, insects and fish scales in its diet. Ofori-Danson (1992) working on the ecology of some *Synodontis* species in Kpong Head-pond (Ghana) have reported the dominant food items of *S. schall* as detritus, insects, oligochaets, nematodes and Hirudinae. Dadebo et al. (2012) reported a similarly diverse diet for *S. schall* in Lake Chamo, including zooplankton, plant materials, insects, fish fry, fish eggs, gastropods, and fish scales. Moreover, various other workers studying the food and feeding habits of *S. schall* in different African water bodies have indicated the polyphagus nature of the species (Adeyemi, 2010; Akombo et al., 2014; Arame et al., 2021) .

The high frequency and substantial volumetric contributions of both plant materials and macro- invertebrates in the stomachs of *S. schall* were a good evidence for its omnivorous feeding habits in Lake Abaya. Various authors have also reported the omnivorous feeding habits of *S. schall* in different African inland water bodies. Baras and Laleye (2003) reported the omnivorous feeding habit of *S. schall* with a strong tendency to predation. Willoughby (1974) described *S. schall* as an omnivorous species feeding on insect larvae and nymph, fish eggs and detritus. Dadebo et al. (2012) also reported the omnivorous feeding habits of *S. schall* in Lake Chamo.

Seasonal variations in the diet of *S. schall* were observed during the present study (Table 2). During the dry season, the diet was dominated by phytoplankton, detritus, insects and macrophytes

(Table 2). The reason for the abundance of phytoplankton during the dry season might be attributed to higher light penetration and reduced water turbulence, which favor autotrophic production (Drakare et al., 2002). Detritus was the second important food of *S. schall* in the dry season (Table 2). The contribution of insects was considerable during the dry season (17.4%). Among insects, Diptera (Chironomidae larvae) was the most important contributing more than 70% by volume of all insect groups. This high contribution of Diptera was probably due to the ease of capture and also their ability to flourish in wide range of environmental conditions (Drakare et al., 2002). Ofori-Danson (1992) also reported the importance of Diptera and other insects in the diet of S, schall in the Kpong Head-pond in Ghana.

Macrophytes were ingested in considerable quantities during the dry season. It is probable that the fish might ingest part of macrophytes incidentally as they pursue their prey in the littoral region where the prey normally seek refuge from predators (Thomaz et al., 2025). More focused study is needed to determine the importance of macrophytes to the nourishment of the species by comparing the nutritive values of the plant fragments in the fore and hind guts of the fish (Thomaz et al., 2025). During the wet season, the contributions of zooplanktons were dominated and widely represented by Daphnia (Table 2). The reason for this was probably due to seasonal reproductive cycle of the cladocerans population, which often peak during rainy season in tropical lakes (Choedchim et al., 2017). Detritus was also an important food item during the wet season. The source of this food category could be the floods that introduce different plant materials into the lake and plant leaves falling into the lake and undergoing partial decomposition. Araoye (1999) reported that the contribution of plant materials and detritus in the diet of *S. schall* during the wet season was high, and such food items were dispersed along the surface water column at this period due to floods and overturn.

From the results of the present study, it was evident that *S. schall* showed a clear ontogenetic dietary shift during its life cycle (Figure 1). Smaller individuals relied widely on phytoplankton and zooplankton, whereas larger fish incorporated more insects, detritus, and macrophytes. Bishai and GideirI (1965) reported that some members of the genus *Synodontis* switch from benthic feeding to surface feeding or vice versa by using ventrally positioned mouth depending on food availability and their size. According to Lalèyè et al. (2006), large size *S. schall* browse on benthic deposit as can be seen from the presence of detritus and mud in the stomachs of large fish. The same authors also noted the importance of fish scales in the diet of *S. schall* as its size increases. Similarly, Dadebo et al. (2012) reported that fish scales become important food items in large size *S. schall* in the neighboring Lake Chamo. Bishai and GideirI (1965) found a significant difference between the diets of large and small *S. schall* in Khartoum. Several other investigators also demonstrated that *S. schall* showed an ontogenetic diet shift as a result of the change in habitat use in different water bodies (Araoye, 1999; Dadebo et al., 2012; Ofori-Danson, 1992). The other probable factor for such dietary variations across size classes might be aligned with the habitat that they survive. Juvenile *S. schall* hide themselves from the risk of predators (Baras & Laleye, 2003). Similar to the present finding, Araoye (1999) and Dadebo et al. (2012) reported that, fry and fingerlings of *S. schall* were usually restricted to the flooded littoral zone of the lake where they feed mainly on zooplankton, insect larvae and other macro-invertebrates.

The concentrations of the five heavy metals detected were generally higher in the kidney and liver compared to muscle tissue (Table 5). For example, Cu levels were elevated in the liver relative to both the kidney and muscle tissues, consistent with findings of Gerenfes et al. (2019) for Enteromious species in Lake Chamo, Ethiopia and Shahid et al. (2016) for *Cyprinus carpio*. This distribution can be explained by the liver's function in detoxification and synthesis of copper-binding metallothioneins, highlighting its role as a crucial bio-indicator for evaluating Cu levels in aquatic ecosystems (Javed & Usmani, 2013). In terms of Cd levels, *S. schall* from Lake Abaya exhibited a muscle tissue concentration of 0.01 mg/kg, which is higher than that of bream (0.009 mg/kg) and mandarin fish (0.0009 mg/kg) from Poyang Lake (Wei et al., 2014). Additionally, Cd concentrations ranging from 0.001 to 0.009 mg/kg were identified in eleven fish species from Rio de Janeiro State, Brazil (Medeiros et al., 2012), but the finding in this study is lower than the 0.03 to 1.57 mg/kg detected in fish from the Pearl River Delta (Cheung et al., 2008). All observed concentrations of the detected heavy metals fall below the limits set by the EU (2001), TFC (2002) and FAO (1983) guideline for human consumption.

Table 5: Comparisons of Concentration of Trace Metals in Fish Muscle Relative to the Standards (mg/kg dry weight).

Parameter (guidelines)	Cu	Zn	Mn	Cd	Ni	References
Present study in fish muscle	0.94	1.26	0.07	0.01	0.05	
FAO	30	50	30	–	–	FAO (1983)
EU	4	–	–	–	–	EU (2002)
Turkish Food Codex	20	50	20	–	–	TFC (2002)

4 Conclusion

This study has clearly shown that *S. schall* in Lake Abaya ingests a wide range of plant based and animal origin of food categories. However, the diet composition of *S. schall* was different based on their size classes and season of sampling. With the exception of some size classes, strong dietary overlap was seen across different size classes. Trace metals analysis revealed that Cu, Cd, Ni, Zn, and Mn were found in all three tissues, while Pb and Co were absent. In the liver, the concentration ranking was Cu > Zn > Mn > Ni > Cd, whereas in muscle and kidney tissues, it was Zn > Cu > Mn > Ni > Cd. From the present study, *S. schall* is an omnivorous in its feeding strategy. Overall, heavy metal concentrations were generally higher in the kidney and liver than in muscle. The level in muscle showed below FAO and EU maximum acceptable limits for human consumption. The present result suggested conducting further metal analysis is required based on simultaneous study including water quality analysis, sediment analysis, and the interaction between feeding ecology with trace metal concentration for further comparisons.

Conflict of Interest

None declared.

Funding

This research was supported by NORAD project

Acknowledgements

The authors are grateful to the Department of Aquatic Sciences, Fisheries and Aquaculture for providing laboratory facilities and the logistics for the field trips. Dr. Andargachew Gedebo, NORAD project coordinator and Hawassa University are acknowledged for providing a vehicle for the field trips. We thank fisherman Asaminew Matte for his assistance during sample collection.

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