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Food and feeding habits of the African catfish *Clarias gariepinus* (Burchell, 1822) (Pisces: Clariidae) in the newly built Ribb Reservoir, north-west Ethiopia

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Abstract

The feeding habits of the African catfish *Clarias gariepinus* (Burchell, 1822) were studied in the newly constructed Ribb Reservoir in Ethiopia during the dry season (January-March) and wet season (June-August) of 2021. Out of 295 fish samples collected, 202 (68.4%) contained food in the gut. Zooplankton (24.4%), detritus (22.8%), macrophytes (16.2%), phytoplankton (14.8%) and insects (11.8%) were the main diets of *C. gariepinus*. Zooplankton (46.2%) and phytoplankton (31.1%) were predominant in the diet during the dry season, but during the wet season, detritus (42%), macrophytes (29.7%) and insects (29.5%) were the predominant food items. The frequency of occurrence and the volumetric contribution of diet items varied significantly ($p<0.05$) between seasons. Schoener's Diet Overlap Index showed a slight ontogenetic shift in the diet of *C. gariepinus* between different size classes. Insects and nematodes were the main diets of smaller-size classes, while plankton, detritus and macrophytes were dominant in the higher-size classes. In general, *C. gariepinus* feeds on both plant and animal food and is considered omnivorous in the reservoir.

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Introduction

The African catfish, *Clarias gariepinus* (Burchell, 1822), is widespread in African waters, from the Nile basin to western Africa and Algeria in the north (Yalcin *et al.*, 2001). In Ethiopia, lakes and river systems have good abundance of *C. gariepinus*. Hence, it is widespread in almost all freshwater systems in Ethiopia, such as the Baro Akobo, Omo-Turkana, Blue Nile (Abay), Atbara-Tekeze, Rift Valley, Wabishebele and Juba drainage basins (Golubtsov and Darkov, 2008; Awoke, 2015).

Numerous studies have been conducted on the food and feeding habits of *C. gariepinus* in Ethiopian waters. These studies showed that *C. gariepinus* hunts a variety of foods depending on the environment in which they live (Dadebo, 2000; Teka, 2001; Tugie and Taye, 2004; Alemayehu, 2009; Dadebo, 2009; Dadebo *et al.*, 2014; Admassu *et al.*, 2015). For example, it ingests various foods such as algae, macrophytes, zooplankton, insects, fishes, detritus, amphibians and grains of sand in several Ethiopian water bodies (Dadebo, 2000, 2009; Admassu *et al.*, 2015). Therefore, based on the above findings, *C. gariepinus* appears to be an opportunistic and omnivorous feeder. However, its dietary composition can vary with seasons and across different environmental conditions (Houlihan *et al.*, 2001). Apart from that, the diet composition of *C. gariepinus* also varies depending on the size of the fish, its maturity and habitat differences (Dadebo *et al.*, 2014).

Investigating the diets of fish species is a subject of continuous research because it makes up a basis for the development of a successful management program on capture fishery and aquaculture (Shalloof *et al.*, 2009). Moreover, information on natural food and feeding habits of fish species enables the identification of trophic relationships present in the aquatic ecosystem and identifying the feeding composition, structure and stability of food webs in the ecosystem (Otieno *et al.*, 2014). The information is also vital for the management of fish within a controlled environment and the formulation of feeds in aquaculture (Adeyemi *et al.*, 2009). Therefore, understanding the food and feeding habits of *C. gariepinus* is a key factor in conducting a successful and sustainable fish culture (Shalloof and Khalifa, 2009).

C. gariepinus is one of the commercially important fish species in the newly constructed Ribb Reservoir. Despite its economic importance, there is no scientific information on the diet and feeding habits of this species in the Ribb Reservoir to support its trophic status and the resulting use of the resource. Therefore, the current study investigated the dietary habits and seasonal and ontogenetic dietary shifts of *C. gariepinus* in the Ribb Reservoir.

Materials and methods

Study area

Ribb Reservoir (11°59'0"N to 12°2'0"N; 38°0'0"E to 38°2'59"E) is an earthen rock dam with a capacity of 234 million m^3 of water, having height and length of 73.5 m and 800 m, respectively (WWDSE, 2010) (Fig. 1). The reservoir was dammed in 2017 on the Ribb River, which is the main tributary of Lake Tana and originates at a distance of 90 km from Gunna Mountain and is bounded by Farta, Ebenat, Libo Kemkem, and Fogera Woredas of the South Gondar Zone in the Amhara Region (Ashenafi, 2011). The reservoir is found in the Lake Tana sub-basin, in the northern part of Ethiopia, which is in the north-eastern part of the Blue Nile basin and the sub-basin has an area of 15320 km^2 (ADSWE, 2015).

The boundary of the study area is classified as a tropical highland with monsoon climate, which is *Wurch* at Gunna Mountain, *Dega* around Debre-Tabor town and *Woina Dega* near the Ribb Reservoir (Ezezew, 2019). The climate of the area is marked by rainy season from May to September, with monthly rainfall ranging from 65 mm in May to 411 mm in July (Sisay, 2017). The subbasin's average annual rainfall was 1,400 mm (Worku, 2021) and the temperature varies throughout the year, ranging from 19°C (December) to 23°C (May), with maximum temperatures of 30°C and minimum of 11.5°C occasionally recorded (Worku, 2021).

Fish sampling and measurements

Fish samples were collected during the dry season (January-March) and wet season (June-August) using gillnets with stretched mesh sizes of 4, 6, 8, 10 and 12 cm. After measuring the total length (TL) to the nearest 0.1 cm using a measuring board and the total weight to the nearest 0.1 g using a digital balance, the fish samples were dissected with scissors and the gut content was preserved in 5% formaldehyde solution for further analysis.

Food and feeding habits

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

Frequency of occurrence (%FO): The number of samples that contained one or more foods was expressed as a percentage of all non-empty intestines (Bagenal and Braum, 1978). The proportion of the population that eats a particular food was estimated using this method.

Volumetric analysis (%V): Foods found in the gut were classified into different taxonomic groups (Windell and Bowen, 1978) and the volume of each food group was measured (Bowen, 1983). Then the volume of a given food category was expressed as a percentage of all food categories present in the intestinal samples. For macroscopic foods, the volume of water displaced within the measured cylinder by the food was expressed as a volumetric percentage of the measured food, as described by Hyslop (1980).

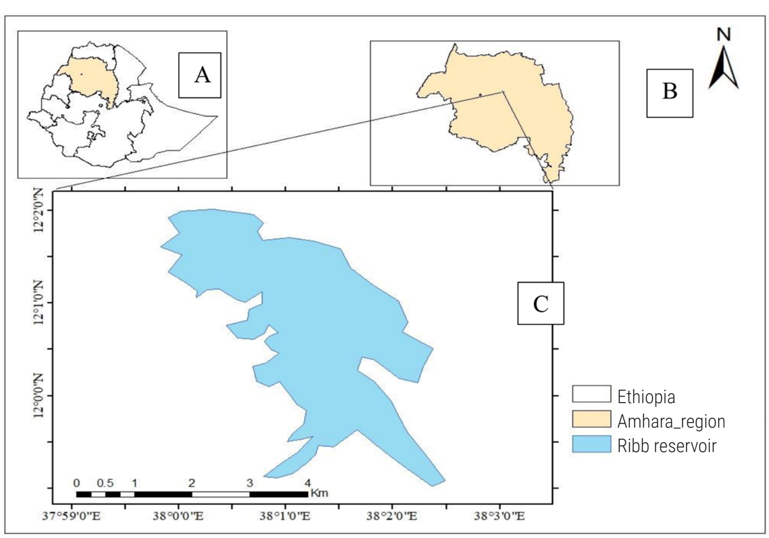

Fig. 1. Location map of (a) Ethiopia, (b) Amhara Region and (c) Ribb Reservoir

Seasonal variation and ontogenetic dietary shift

Seasonal variation in the type of food consumed by *C. gariepinus* was investigated based on the percent of frequency of occurrence and volumetric proportion during the dry and wet seasons. For the ontogenetic dietary shift, the fish specimens were divided into three size classes *viz.,* I: 30-39.9 cm TL (lower), II: 40-49.9 cm TL (intermediate) and III: ≥50 cm TL (higher) (Dadebo *et al.*, 2014). Then, the percentage mean volume of different food items was calculated (Schoener, 1970; Wallace, 1981).

Data analysis

Chi-square (χ^2) test was used to compare the frequency of occurrence of the different food categories in the dry and wet season samples. The independent sample *t*-test was used to compare the volume of the different food categories consumed during wet and dry seasons. Dietary overlap between different size classes was calculated as percentage overlap using Schoener Diet Overlap Index (SDOI) (Schoener, 1970; Wallace, 1981):

$$\alpha = 1 - 0.5 \left(\sum_{i=1}^{n} |Pa_i - Pb_i|\right)$$

where, α is the percentage overlap of the SDOI between size class "a" and "b" whereas, Pa_i and Pb_i 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 295 specimens, ranging in total length (TL) from 30 to 72 cm and total weight (TW) from 230 to 1897 g, were collected. Stomachs of 202 specimens (68.4%) contained food, while 93 (31.5%) were empty. The identified diets of *C. gariepinus* consisted of zooplankton, detritus, macrophytes, phytoplankton, insects, fish, nematodes, molluscs, fish scales and digested materials. Of these foods, the first five made up the bulk of the food eaten, while fish, nematodes and molluscs were less important. The remaining dietary elements, such as fish scales and digested materials, were relatively unimportant for the diet of *C. gariepinus* (Table 1).

Zooplankton were the dominant food items in the diet of *C. gariepinus* occurring in 48.5% of the stomach and accounting for 24.4% of the total volume of food consumed. Among zooplankton groups, Cladocera was dominant, forming 39.6% in stomach contents and 17.2% of the total volume of the food items. Detritus and macrophytes were important food items next to zooplankton, occurring in 35.6 and 29.7% of the stomach and contributing to 22.8 and 16.2% of the total volume of the food items, respectively. Consumption of rotifers and copepods was minimum.

Phytoplankton made up 28.2% of the food and accounted for 14.8% of the total volume. Among phytoplankton, diatoms, blue-green algae, green algae and euglenoids were identified at frequencies of 14.9, 16.8, 7.9 and 1.5% and volumes of 5.3, 5, 4.1 and 0.4%, respectively. The contribution of insects was higher than that of other foods (Table 1). Diptera, Ephemeroptera, Hemiptera and Plecoptera were the most abundant foods among insects, accounting for 34.7, 27.7, 25.7 and 20.3% of the occurrence and volumetric proportions of 3.8, 3, 2.3 and 1.5% respectively.

Seasonal variations

The frequency of occurrence of phytoplankton, zooplankton, insects, macrophytes and detritus in the diet of *C. gariepinus* varied significantly between the dry and wet seasons ($p<0.05$). Similarly, the volumetric contributions of phytoplankton, zooplankton, macrophytes, detritus, nematodes and molluscs were also significantly different during the two seasons ($p<0.05$, Table 2).

Zooplankton were present in 71.6% of guts and accounted for 46.2% of the diet by volume during the dry season, while during the wet season, they were present only in 25% of guts and accounted for only 4.5% of the total volume (Table 2). Among zooplankton, Cladocera was the predominant group, occurring in the dry season at 53.9% and accounting for 31.1% of the dietary volume, while in the wet season, it occurred at 25% and contributed 4.5% volumetrically. The contribution of phytoplankton was 55.9% in the dry season, which was 31% of the total volume. Phytoplankton were absent in the wet season.

The volumetric contribution of insects to the diet of *C. gariepinus* was similar during the dry and wet seasons, but the contribution of different taxa varied in both seasons (Table 2). The contribution of Diptera (5%) and Ephemeroptera (3.2%) was higher in the wet

Table 1. Frequency of occurrence and volumetric contribution of different food items consumed by *C. gariepinus* in Ribb Reservoir (n = 202)

Food items	Frequency of occurrence		Volumetric contribution	
	Number	%	Volume (ml)	%
Phytoplankton	57	28.2	152.6	14.8
Green algae	16	7.9	41.8	4.1
Blue-green algae	34	16.8	51.3	5.0
Diatoms	30	14.9	55.5	5.3
Euglenoids	3	1.5	4.0	0.4
Zooplankton	98	48.5	251.9	24.4
Cladocera	80	39.6	177.6	17.2
Copepoda	26	12.9	26.9	2.6
Rotifera	24	11.9	47.5	4.6
Insects	162	80.2	121.3	11.8
Diptera	70	34.7	38.9	3.8
Ephemeroptera	56	27.7	31.4	3.0
Plecoptera	41	20.3	15.5	1.5
Hemiptera	52	25.7	23.8	2.3
Trichoptera	5	2.5	3.9	0.4
Coleoptera	16	7.9	7.9	0.8
Fish (*O. niloticus*)	4	2.0	48.0	4.6
Fish scales	21	10.4	5.9	0.6
Macrophytes	60	29.7	167.3	16.2
Detritus	72	35.6	235.1	22.8
Nematodes	45	22.3	24.5	2.4
Molluscs	38	18.8	20.4	2.0
Digested materials	10	5.0	5.1	0.4

Volume of the major food items in bold adds up to 100% in volumetric analysis

Table 2. Relative contribution of different food items in the diet of *C. gariepinus* during the dry (n = 102) and wet seasons (n = 100) in Ribb Reservoir

Food items	Frequency of occurrence (%)		Volumetric contribution (%)	
	Dry season	Wet season	Dry season	Wet season
Phytoplankton	55.9[b]	-	31.0[a]	-
Green algae	15.7	-	8.5	-
Bluegreen algae	33.3	-	10.4	-
Diatoms	29.4	-	11.3	-
Euglenoids	2.9	-	0.8	-
Zooplankton	71.6[b]	25[a]	46.2[a]	4.5[b]
Cladocera	53.9	25	31.1	4.5
Copepoda	25.5	-	5.5	-
Rotifera	23.5	-	9.6	-
Insects	64.7[b]	96[a]	11.7[a]	11.8[b]
Diptera	22.5	47	2.5	5.0
Ephemeroptera	24.5	31	2.9	3.2
Plecoptera	27.5	13	2.3	0.6
Hemiptera	19.6	32	3.0	1.7
Trichoptera	2.9	2	0.6	0.2
Coleoptera	2.9	13	0.4	1.1
Fish (*O. niloticus*)	2.0[b]	2[a]	3.0[a]	6.1[b]
Fish scales	13.7[b]	7[a]	0.4[a]	0.7[b]
Macrophytes	2.9[b]	57[a]	1.4[a]	29.7[b]
Detritus	11.8[b]	60[a]	1.7[a]	42.0[b]
Nematodes	21.6[b]	23[a]	1.4[a]	3.3[b]
Molluscs	23.5[b]	14[a]	2.9[a]	1.2[b]
Digested materials	2.9[b]	7[a]	0.3[a]	0.7[b]

Values of respective food items under the same category bearing different superscript letters are significantly different (p<0.05)

season than in the dry season. On the other hand, the consumption of Hemiptera (3%) and Plecoptera (2.3%) decreased during the dry season. The frequencies of macrophytes (2.9%) and detritus (11.8%) were lower in the dry season than in the wet season. Similarly, the volumetric contributions of macrophytes and detritus increased from the dry season (1.4 and 1.7%) to the wet season (29.7 and 42%) (Table 2).

Ontogenetic dietary shift

Phytoplankton contributed 9.8% of the total volume in the lower size class of *C. gariepinus*, 11.9% in the intermediate size class and 17.3% in the higher size class (Fig. 2). Similarly, the contribution of zooplankton was 10% of the total volume in the lower size class, but in the lower size class, zooplankton was heavily consumed, accounting for 25.4% of the total volume and further increasing to 27.9% of the total volume in the higher size class.

The consumption of macrophytes by *C. gariepinus* increased from lower to the higher size class. The volumetric contribution also increased from 6 to 18.5%, as seen in Fig. 2. Similarly, the importance of detritus increased from the lower size class to the intermediate size class and further to the higher size class, with the respective volumetric proportions of 8.8, 22.2 and 26.8% of the total volume. On the other hand, the volumetric contribution of insects decreased greatly with the size of the fish, which accounted for 44.9% in the lower size class and 15.8% in the intermediate size class and continued to decrease in size in the higher class. In general, a slight ontogenetic dietary switch was noted during the life of *C. gariepinus*. There was significant dietary variation in the lower and intermediate sizes classes (p=0.58) and lower and higher size classes (p=0.36, p<0.60; Table 3). In contrast, it was not significant (p>0.60) in intermediate and higher sizes classes (p=0.78).

Discussion

The diet of *C. gariepinus* from the Ribb Reservoir constitutes zooplankton, detritus, macrophytes, phytoplankton, insects, fish, nematodes, molluscs, fish scales and digested material.

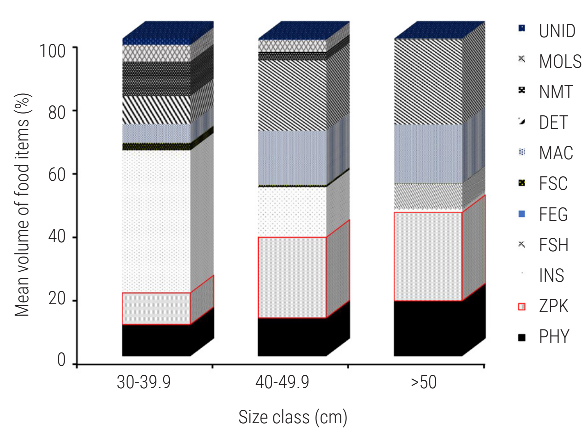

Fig. 2. The relative volume of food items consumed by different size classes of *C. gariepinus* from Ribb Reservoir (PHY = Phytoplankton, ZPK = Zooplankton, INS = Insects, FSH = Fish, FSC = Fish scales, MAC = Macrophytes, DET = Detritus, NMT = Nematodes, MOLS = Molluscs)

Table 3. Relative volume of food items consumed by different size classes of *C. gariepinus* from Ribb Reservoir

Food type	Lower size class	Intermediate size class	Higher size class
PHY	9.8	11.9	17.3
ZPK	10.0	25.4	27.9
INS	44.9	15.8	1.2
FSH	0.0	0.0	7.8
FEG	0.0	0.0	0.0
FSC	2.3	0.7	0.1
MAC	6.0	17.1	18.5
DET	8.8	22.2	26.8
NMT	10.8	2.6	0.0
MOLS	5.3	3.9	0.3
DIMA	2.1	0.4	0.1
TOTAL	100.0	100.0	100.0

PHY = Phytoplankton, ZPK = Zooplankton, INS = Insects, FSH = Fish, FSC = Fish scales, MAC = Macrophytes, DET = Detritus, NMT = Nematodes, MOLS = Molluscs, DIMA = Digested materials

In the present study, foods of plant origin such as detritus, macrophytes and phytoplankton were the most important, along with zooplankton, which is more or less similar to those in Lake Babogaya (Abera, 2007), in Lake Koka (Dadebo *et al.*, 2013, 2014), Lake Hayq (Alemayehu, 2009) and the Asi River (Yalcin *et al.*, 2001). The composition of the diet of *C. gariepinus* showed seasonal variations which could be due to the opportunistic feeding nature of the fish, which has the potential to switch from one diet to another, as in Lake Hawassa (Dadebo, 2000; Dadebo *et al.*, 2014; Tekle-Giorgis *et al.*, 2016), Lake Langano (Teka, 2001), Lake Babogaya (Abera, 2007), Lake Hayq (Alemayehu, 2009). Several investigators (Philipart and Ruwet, 1982; Matipe and De Silva, 1985; Abera, 2007) concluded that the seasonal variation in food habits could be due to the opportunistic nature of the fish, which is capable of shifting from one diet to another depending on spatial variations in availability of the diet in the aquatic ecosystem. Variations in the diet may also be due to seasonal variations in food production in the reservoir, which is supported by studies from Lake Tana (Dejen *et al.*, 2004; Wondie and Mengistu, 2014) and the Gilgel-Gibe Reservoir in the Omo Turkana basin for *Oreochromis niloticus* and *Labeobarbus intermedius* (Wakijira, 2013).

During the wet season, the diet of *C. gariepinus* lacked phytoplankton. This could be due to the high turbidity in the reservoir, which may have resulted in low light transmission and reduced photosynthetic activity. As reported by Mequanent *et al.* (2021), in the Ribb Reservoir, plankton density decreased due to the runoff of water via the spillway, causing plankton to move out of the reservoir. In addition, a large amount of detritus could escape from the catchment area and accumulate in the sediment of the reservoir. This result is consistent with the results in the Shallo swamp in Ethiopia (Tekle-Giorgis *et al.*, 2016); in Lake Koka (Dadebo *et al.*, 2014) and in the upper Blue Nile River for large cyprinid fishes (Teshome *et al*., 2023).

The current study showed a slight ontogenetic dietary change in the class of *C. gariepinus*. Dietary change was observed in both lower and intermediate size classes (p=0.58) and lower and higher size classes (p=0.36). This is similar to the study conducted by Mingist *et al.* (2023) in Ribb Reservoir, wherein they reported that *L. intermedius* showed a slight ontogenetic dietary shift among different size classes. There was a significant ontogenetic dietary shift between lower and intermediate size classes (p=0.45) and between lower and higher size classes (p=0.30). However, the investigators reported that there was no significant ontogenetic dietary shift between intermediate and higher-size classes (p=0.69). On the contrary, Dadebo *et al.* (2014) reported that there were no significant variations in the diet of individuals in the smallest and intermediate size classes of *C. gariepinus* (p=0.69) and the intermediate and the largest size classes (p=0.86). However, significant variation in the diet of the smallest and the largest size classes was reported (P=0.55). In addition, the contribution of different diet groups to the three size classes in the wet and dry seasons is also well discussed by Dadebo *et al.* (2014).

In the current investigation, ontogenetic dietary shift revealed that the importance of insects was high in the smaller size classes and decreased with increasing fish size while the importance of detritus and macrophytes was less in the lower size classes and increased with the size of the fish. This could be because juvenile fish require a large amount of protein to support their growth rate and metabolism, as indicated by Benavides *et al.* (1994) and Dadebo *et al.* (2014). A similar ontogenetic change in diet was also reported by Tekle-Giorgis *et al.* (2016) in Lake Hawassa. The researchers reported that contributions from zooplankton, detritus and phytoplankton increased with fish size, while contributions from insects, fish, fish eggs and gastropods decreased with fish size, which is consistent with studies by Agembe *et al.* (2018), Dadebo (2000) and Admassu *et al.* (2015).

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