SCHOOL OF GRADUATE STUDIES

DIET COMPOSITION AND FEEDING HABITS OF *CYPRINUS CARPIO* (LINNAEUS 1758) (PISCES: CYPRINIDAE) IN LAKE AREKIT, ETHIOPIA

Msc THESIS

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Diet Composition and Feeding Habits of *Cyprinus Carpio* (Linnaeus 1758) (Pisces: Cyprinidae) In Lake Arekit, Ethiopia

A Thesis Submitted To School of Graduate Studies, for the Fulfillment of the Requirements for the Degree of Masters in Biology

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Thesis Paper Approval Sheet

We hereby certify that we have read and evaluated this Thesis prepared titled **"Diet Composition and Feeding Habits of *Cyprinus carpio* (Linnaeus 1758) (Pisces: Cyprinidae) in Lake Arekit, Ethiopia"** prepared under our guidance by Injigu Wendimu and recommend that the thesis shall be submitted as fulfilling the requirements for the award of Masters of degree in Biology.

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As members of the Board of Examiners of the Masters of Science Thesis open defense examination, we have read and evaluated this Thesis prepared by Injigu Wendimu and we examined the candidate. We hereby certify that, the thesis is accepted for fulfilling the requirements for the award of degree of Masters of Science in Biology.

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Declaration

I hereby declare that this thesis, titled: "Diet Composition and Feeding Habits of *Cyprinus carpio* (Linnaeus 1758) (Pisces: Cyprinidae) in Lake Arekit, Ethiopia" has been composed entirely by myself and has not been submitted for any other degree or qualification. The work satisfies with the regulations of the University and meets the accepted standards with respect to originality and quality and all sources of information have been specifically acknowledged.

Name: Injigu Wendimu

Signature ____________________ Date_________________________

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First of all, praises and thanks to God, the Almighty, for his blessings throughout my life in preparing this thesis paper. Next, I would like to express my gratitude and appreciation for my main advisor Solomon Wagaw (PhD) and Co-advisor Ashenafi T/Mariam (Ass. Professor) whose guidance, support and encouragement have been invaluable throughout this prepared thesis. Additionally I am grateful to everyone who assisted with the field and laboratory work, particularly the Lake Arekit fishermen as well as I would also like to thank my honorable parents Ato Wendimu Taddesa and wezaro Gete Abota who have been working hard to teach me to learn and change my self and whose blessings and help is still with me and my beloved wife wezaro Gobene Bedassa who has been supporting and encouraging me intellectually and financially. Finally, I would also like to thank Wolkite University's Biology Department Laboratory technician Mr. Minichil Addis for providing the facilities and assistance during microscopic identification of fish’s food items.

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List of Abbreviations

ANOVA: ------------------Analysis of Variation

GIIi: -----------------------Geometric Index of Importance

IOP: -----------------------Index of Preponderance

IUCN: --------------------International Union for Conservation of Nature

SD: -------------------------Standard deviation

TL: -------------------------Total length

TW: -----------------------Total Weight

Sp: -------------------------Species

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General organization of the thesis

This thesis is organized into six chapters including an introduction to the findings from the study conducted on the diet composition and feeding habits of *Cyprinus carpio* in the Lake Arekit, Ethiopia.

Chapter 1: This introduces the general overview, outlines the research questions and objectives, reveals research gaps, and gives highlights of the topic area.

Chapter 2: This chapter reviews the literature on the distribution, diet composition, feeding habits, and seasonal and ontogenetic dietary changes of *C. carpio*.

Chapter 3: In this chapter, the study area, biodiversity, sampling methods, fish specimen measurements, gut content analysis, and data analysis techniques are described.

Chapter 4: This chapter discusses the stomach contents of *C. carpio* in Lake Arekit, their diet composition, feeding habits, and classification of prey, as well as seasonal variations in volumetric contribution and feeding preferences across different size classes.

Chapter 5: The chapter discusses the research findings in relation to those of other researchers studied in various geographical locations.

Chapter 6: This chapter offers a summary of the diet composition and feeding habits of *Cyprinus carpio* (Linnaeus 1758) from Lake Arekit, Ethiopia, along with recommendations for fisheries management, conservation strategies, and suggestions for future research in the area.

The data on *C. carpio* in Lake Arekit led to the publication of one article and a manuscript currently under review in Scopus and Web of Science journals.

1. “Population Dynamics of the Common Carp (*Cyprinus carpio* L. 1758) Stock in Lake Arekit, Ethiopia: Implications for Management and Conservation” Journal of *Applied Ichthyology; Volume 2024, Article ID 9940938.*

2. "Seasonal feeding activity and ontogenetic dietary shifts of the common carp (*Cyprinus carpio*) in Lake Arekit, a small, eutrophic lake in Ethiopia" submitted to the journal of "*Aquaculture, Fish and Fisheries Status”*. **Status: Under review.**

Abstract

The diet composition and feeding habits of Cyprinus carpio (Linnaeus, 1758) were examined using 209 fish samples from Lake Arekit. The species' feeding patterns were determined through numerical indexes (frequency of occurrence and volumetric contribution) and composite indexes (Index of Preponderance (IOP) and Geometric Index of Importance (GIIi)). Among the 209 specimens, 174 (83.3%) displayed a range of dietary items in their stomachs. Detritus emerged as the primary food source for C. carpio, followed by macrophytes, insects, and zooplankton. A lesser amount of phytoplankton, nematodes, and ostracods were also consumed. Based on the findings, C. carpio can be classified as a detri-omnivore, as it consumes benthic species like nematodes, ostracods, and insect larvae. Seasonal fluctuations in food item consumption were noted ($p < 0.05$), with higher intake during the rainy season and reduced consumption in the dry season. Significant variations in food preferences were observed among size groups ($p < 0.05$). Smaller size classes preferred foods of animal origin, such as ostracods, zooplankton, and insects, while macrophytes and detritus were more prevalent in the largest class. This study enhances our understanding of C. carpio's diet in Lake Arekit. Still, further research is necessary to explore the diet across the fish's lifespan and monthly, considering various environmental conditions.

Key Words/Phrases*:* *Cyprinus carpio*, detri-omnivore, Geometric Index of importance (GIIi), Index of Preponderance (IOP), ontogenetic dietary shifts

CHAPTER 1. INTRODUCTION

1.1. Background of the study

Cyprinus carpio has a broad distribution and has been successfully introduced in various environments due to its remarkable ability to adapt to changing conditions (Lyach, 2022; Kang *et al*., 2023). While it can be found in nearly every country, it is trendy in Asia and Europe (Parkos and Wahl, 2014). Further research is necessary to comprehend the biology of *C. carpio*, despite its widespread introduction in Ethiopian waters (Endalh Mekonnen *et al*., 2019; Assefa Tessema *et al*., 2020). Understanding its feeding ecology, especially potential dietary changes as it grows, is crucial for effective fisheries management (Solomon Wagaw *et al*., 2022; Yirga Enawugaw *et al*., 2023).

Feeding and food composition information is used to evaluate the biological and ecological roles of fish (Solomon Wagaw *et al*., 2022; Dou *et al*., 2023). Gut content analysis helps in determining the feeding behaviors of fish species in their environments, such as feeding intensity, trophic level, niche breadth, and intra- and interspecific competition (Xia *et al*., 2020; Imran *et al*., 2021). According to Alieva *et al*. (2023), age, size, and seasonal variations significantly influence the diet composition of fish. Understanding fish conditions in their natural habitat can be enhanced by considering ontogenetic dietary shifts and seasonal changes, as suggested by Solomon Wagaw *et al*. (2022) and Kwak *et al*. (2023). The dietary composition of *C. carpio* in various aquatic environments worldwide has been studied by several researchers (Elias Dadebo *et al*., 2015; Sahtout *et al*., 2018; Achakzai *et al*., 2022; Eljasik *et al*., 2022).

Elias Dadebo *et al*. (2015) highlighted that species adaptations, life cycle stages, and biological interactions significantly influence fish feeding behavior. Environmental factors, as pointed out by Sahtout *et al*. (2018), also play a crucial role in shaping dietary habits and food content. In Lake Arekit, *C. carpio* plays an ecological and commercially significant role in fishing (Solomon Wagaw *et al.,* 2024a and b). Their biological characteristics including growth patterns, length-weight relationships, reproduction, fecundity, mortality, exploitation rates, and morphometry, are only partially documented (Solomon Wagaw *et al*., 2024a and b) and this study examines how the diet composition of *C*. *carpio* changes as they grow and the potential impact on the lake's food web dynamics by examining their dietary patterns across different size categories in Lake Arekit. Research on the food composition, ontogenetic diet changes, and feeding habits of *C*. *carpio* in Lake Arekit remains lacking despite the species' ecological and economic significance. For the species' survival in the lake, this knowledge is thought to be crucial. Thus, the purpose of this study was to examine the feeding patterns of *C*. *carpio* in Lake Arekit, as well as diet differences according to size categories and seasons.

1.2. Statement of the problem

By contributing to animal protein intake, employment generation, household incomes and foreign exchange earnings, fish play an important role in the economy of developing and developed countries (Rishikanta *et al.*, 2015). For the identification of the trophic relationships present in aquatic ecosystems, feeding composition, structure and stability of food webs, it is important to describe the food and feeding habits of fish (Hussian *et al.,* 2019).

Even though, there are some research works conducted in different water bodies of Ethiopia on food and feeding habits of different fish species such as Abebe Getahun *et al.* (2020) on the juvenile and adult Common carp (*Cyprinus carpio*) in lake Ziway, Elias Dadebo *et al.* (2013) on African big barb (*Labeobarbus intermedius*) in Lake Koka, Solomon Wagaw *et al.* (2022) on Nile tilapia (*Oreochromis niloticus*) (Linnaeus, 1758) in Lake Shala, there was no information on the food and feeding habits of *C. carpio* in Arekit Lake. Therefore, this study was aimed to improve the understanding of the food and feeding habits of the common carp (*C. carpio*) of the study area that can be used as a reference in further depth for other researchers (Hussian *et al.*, 2022) and it establishes the basis for the development of effective fisheries management programs in the study area (Yirgaw Teferi *et al*., 2000).

1.3. Significance of the study

The study of diet composition and feeding habits of *Cyprinus carpio*, particularly in Lake Arekit, carries substantial significance for several reasons including:

- ✓ Ecological Insights: Understanding the feeding patterns and dietary changes of *C. carpio* is crucial for grasping its role within Lake Arekit's food web. By analyzing how the diet of *C. carpio* evolves with growth and seasonal changes, this study will provide valuable insights into its ecological interactions, such as competition with other species and its impact on the lake's trophic structure which its knowledge is vital for maintaining the ecological balance and health of the aquatic environment.
- ✓ Fisheries Management: Lake Arekit is an important site for fishing activities, and *C. carpio* plays a significant role in the local fisheries both economically and ecologically.

Therefore, documenting the dietary patterns of *C. carpio* can help to develop effective fisheries management strategies and it will allow for better predictions of how changes in fish diets could affect fish populations and the overall lake ecosystem, thus informing sustainable fishing practices and conservation efforts.

- ✓ Economic Benefits: The common carp is a key species contributing to local economies through its role in food security, employment, and income generation. By improving our understanding of its feeding habits and dietary needs, this study can aid in optimizing fishery practices, which in turn can enhance fish yields and economic benefits for local communities. This is particularly relevant in developing regions where fisheries are a crucial component of the local economy.
- ✓ Scientific Contribution: While previous studies have explored the feeding habits of *C. carpio* in various locations, there is a notable gap regarding its dietary patterns in Lake Arekit. This research will fill this gap, providing a new dataset that can serve as a reference for future studies. It will also contribute to the broader scientific understanding of how environmental and biological factors influence the feeding ecology of *C. carpio* and the findings from this study will lay the groundwork for future research on the food and feeding habits of *C. carpio* and potentially other fish species in Ethiopian waters. Generally, this study is poised to offer critical insights into the feeding ecology of *C. carpio*, which is essential for informed fisheries management, ecological conservation, and economic development in the region and the outcomes will not only benefit local stakeholders but also contribute to the global body of knowledge on freshwater fish ecology.

1.4. Research questions

- What are the diet compositions of the *C. carpio* in Lake Arekit?
- Is there variation in the diet composition in *C. carpio* during the dry and wet months in the Lake?
- Is there any ontogenetic dietary shift in *C. carpio?*

1.5. Objectives

1.5.1. General objective

To generate a baseline information on Diet Composition and Feeding Habits of *Cyprinus carpio* (Linnaeus 1758) (Pisces: Cyprinidae) in Lake Arekit, Ethiopia".

1.5.2. Specific Objectives

- To identify the diet composition in the gut contents of *C. carpio* in Lake Arekit.
- To evaluate the variations of diet composition in *C. carpio* during the dry and the wet months in the Lake.
- To analyze the ontogenetic dietary shift in different size classes of *C. carpio.*

CHAPTER 2. REVIEW LITERATURE

2.1. Some Characteristics of Common carp (*Cyprinus carpio*)

The common carp (*Cyprinus carpio*) is characterized by its robust and adaptable morphology and its features a deep, laterally compressed body covered with large, cycloid scales, which can vary in color from golden-yellow to olive-brown (Welcomme *et al.,* 2010). The carp has a distinctive head with two pairs of barbels located on each side of the upper jaw, which are sensory organs used to locate food on the bottom substrates and Its mouth is sub-terminal and can extend to help in foraging (Nattabi, 2018). The dorsal fin of the common carp is long and consists of a single spiny part followed by a soft-rayed section, while the anal fin is similarly structured with a long base and its caudal fin is forked and provides strong propulsion (Nair *et al.*, 2024). The body shape and fin structure contribute to the carp's efficient swimming in a variety of aquatic environments, from stagnant ponds to flowing rivers (Bressman, 2022).

Figure 1: Commercially important Common carp (*C. carpio*)

2.2. Distribution of the Common carp (*Cyprinus carpio*)

Carps were widespread across the world, but the extensive environmental damage that they cause makes them a part of the “World’s Worst Invasive Species” by the International Union for the Conservation of Nature (IUCN) (Oyugi, 2012). Carps were known to be an ecosystem engineer, which means that they modify and alter the state of the water bodies they inhabit (Weber and Brown, 2009). Common carp is native to Europe but has been widely introduced and is now found worldwide except for the poles (Hanel *et al.,* 2011). It was probably the first fish species whose distribution was widely extended by the human introduction, since its introduction by the Romans from the River Danube throughout Europe and is also accounts for the world’s highest farm fish production (Abdelhamid *et al.*, 2022).

Common carps exploit large and small man-made and natural reservoirs, and pools in slow or fast moving streams (Sarkar *et al.,* 2018). However, they prefer larger, slower-moving bodies of water with soft vegetated sediments but they are tolerant and hardy fish that thrive in a wide variety of aquatic habitats (Sarkar *et al.,* 2018). Eventhough their preferred temperature range is normally between 15 and 32^{o}C, they can survive in a wide range of temperatures including ice-covered lakes (at about 2^{o}C) and much warmer ponds (up to about 40^{o}C), they can also withstand low-quality water with low oxygen levels and slightly salted water (Koehn *et al.,* 2016). Ecosystem alterations induced by common carp have great potential to influence native fish populations by which reducing or eliminating aquatic macrophytes and disrupting substrates, common carp may indirectly reduce the abundance of other fishes through reductions in spawning and nursery habitats (Weber and Brown, 2011).

Additionally, increased turbidity, commonly associated with common carp populations, may alter piscivore and planktivore foraging behavior and reduce success (Shoup and Wahl, 2009), affecting fish condition, growth and survival. Thus, common carp may interact with and have effects on native fish through multiple complex mechanisms (Shoup and Wahl, 2009). On the basis of qualitative and quantitative analysis of gut contents, common carp is an omnivorous fish that can consume a wide range of food items like worms, molluscs, zooplankton, aquatic vegetation, plant debris, detritus, and insects (Ramirez *et al.*, 2014). The diversity of its diet makes this species resistant to food web change and capable of inhabiting a wide variety of habitats and common carp primarily feeds on benthic macro-invertebrates (chironomids) and zooplankton, but the bulk of its diet consists of detritus (Rahman *et al.*, 2015). Common carp generally ignores phytoplankton, strongly selects benthic macro-invertebrates and weakly selects zooplankton (Hassan *et al*, 2015).

2.3. *Cyprinus carpio* in case of Ethiopia

The introduction of *C. carpio* in African freshwater ecosystems began in South Africa in its largest impoundment of Lake Gariep (Ellender *et al*., 2008) and it was first introduced to Aba Samuel Dam (Awash River basin) in 1940 from Italy and then introduced to Lake Koka in the late 1960s, Later has been introduced in Lake Ziway in the late 1980s, in highland lakes such as Ashengie, Ardibo, and Maybar for food security purpose, and the introduction was successful (Golubtsov and Darkov 2008 in Abebe Getahun 2017).

2.4. Food and feeding habits of *C. carpio*

The study of fish feeding, characteristics of their feeding behavior, effects of various environmental factors and physiological status on feeding efficiency is the basic directions of ichthyological research (Cooke *et al.,* 2020). Fish are characterized by having very high diversity of species adaptations and one of these is feeding adaptation (Diana Hook, 2023). The composition of the consumed food, the width and variability of the food spectrum, the way of obtaining the food and dynamics of feeding may differ (Rahman, 2015). Food habits of fish are highly variable and depend on a wide range of factors including the species and age of the fish, the availability of preferred food and the combination of fish species (Rahman, 2015). Researches on natural fish feeding behavior allows researchers to determine the trophic linkages found in aquatic environments, as well as the structure, stability, and makeup of food webs through feeding (Hendy *et al.*, 2023).

Food and feeding habit of fish are also important biological factors for selecting a group of fish for culture in ponds to avoid competition for food among themselves and live in an association and to utilize all the available food (Manon and Hossain 2011).

The study of the feeding habits of fish and other animals based on analysis of stomach content has become a standard practice (Verma *et al.,* 2020). Stomach content analysis is widely used in the study of fish feeding habits and provides an important means of investigating trophic relationships in aquatic communities (Verma *et al.,* 2020). According to Maritz *et al.* (2021) many factors were responsible for the changes in diet, and can be divided into two categories: External factors (example: habitat, food supply, predation risk) and Internal factors (example: anatomical structures, behavior, physiological demands).

In many species, dietary changes are associated with habitat shifts and the type and size of food item consumed may vary with age and size of the fish and this was mainly because fish can only feed on food items that can fit into their mouth and what their gut can digest (Maritz *et al.*, 2021). Also, Al-Lamy and Taher (2016) described that feeding relationships of fish population differ greatly, depending on species adaptations, different stages of life cycle and biological relationships between species such as predation and environmental factors affect food and feeding habits of fish, as an example, seasonal changes in temperature lead to blooming of phytoplankton and algae, and then increasing zooplankton which consider an important food for many fish especially at early life; in addition to that food quality and quantity play an important role in feeding relationships among species.

The feeding conditions of *C. carpio* vary depending on its diet and seasonal feeding activities, according to researches conducted by several researchers on the fish's feeding behaviors in its natural habitat (Kasumyan *et al*., 2024). This variation in the types of organisms consumed could be due to the fact that it changes its location in certain periods for feeding purposes and the presence of benthic organisms, detritus, and mud in its digestive tract throughout the year confirms that the species feeds at the bottom of the water body (Kaur and Singh, 2010). Therefore *C. carpio* is an omnivorous bottom feeder fish since it disturbs the bottom sediment while feeding, it was known to increase water turbidity (Rahamn *et al.*, 2022).

In case of Ethiopia for example Abebe Tesfaye *et al.*, (2020) reported that *C. carpio* in Lake Ziway feeds on a variety of food items (macrophytes, detritus, insects, Phytoplankton, zooplankton, nematodes, ostracods, gastropods and unidentified animals) and reported it as omnivorous fish type.

2.5. Seasonal variations in the diet of *Cyprinus carpio*

The food habit of different fish may also be varies from month to month and this variation might be due to changes in the composition of food organisms occurring at different seasons of the year (Menasria and Bensouilah, 2018). It has been documented that natural food material is not available in equal quantity throughout the year, and there is a clear fluctuation in it (Richter and Dawes, 2008). Therefore, it is important to emphasize that the effect of seasonality should always be considered in the studies on natural feeding of fish, because the temporal changes of biotic and abiotic factors alters the structure of the food web along the year and as a consequence, the fish may often shows temporal and seasonal diet shifts (Diana Hook, 2023). According to Gul *et al.,* (2010) the consumption of Rotifera and Copepoda was observed to decrease and the consumption of Cladocera was observed to increase in wet months. They also it was reported that the consumption of benthic organisms (especially Chironomus) was observed to increase in dry months Gul *et al.,* (2010).

According to Mangi and Memon's (2017) observations, the gut's percentage of fullness was highest during the rainy months and subsequently decreased to its lowest during the dry months. The stomach contents of *C. carpio* contained leaves and stems of aquatic plants in which percentage of plant parts and molluscs were largest during the wet months and lowest during the dry months while the percentage of insects was lowest in the wet months and higher in the dry ones (Mangi and Memon's (2017). Sahtout *et al.* (2018) showed that the coefficient of stomach vacuity index exhibits a highest value in wet months, then a progressive reduction to reach its smallest value in dry months.

Crustaceans showed high values of index of relative significance (IRI) during summer and low values were recorded during winter in the seasonal fluctuations of the various food items, as measured by the index of relative importance (%IRI) of the food items (Sahtout *et al.*, 2018). Fish and plant debris were only seen during the wet season and were not present during the dry season, while phytoplanktons, insects, and unknown objects were spotted throughout the year (Sahtout *et al.*, 2018).

In Ethiopia, Elias Dadebo *et al.,* (2016) reported that *C. carpio* mainly feed on detritus and macrophytes during the wet months whereas insects accounted the largest food volume in the dry months. Also, the presence of benthic organisms and detritus in its digestive tract throughout the year confirms that the species feeds at the bottom of the water body (Rahman *et al.,* 2015). The contribution of detritus in the diet of the common carp was low in dry months and high in rainy months and the highest volume of detritus during the wet months was due to the fact that large quantities of plant materials and debris carried into the lake by runoff during the rainy months and create a larger load of sediments (Elias Dadebo *et al.*, 2015) on lake Koka, and Abebe Tesfaye *et al.,* 2020) on lake Ziway.

The contribution of insects in the diet of common carp was recorded high during dry and low during wet months in Lake Ziway Abebe Tesfaye *et al.,* 2020). Phytoplankton relatively observed high during dry months and low in wet months in the diet of common carp (Elias Dadebo *et al.*, 2015, and Abebe Tesfaye *et al.,* 2020) in Lakes Koka and Ziway respectively.

2.6. The ontogenetic dietary shifts of *Cyprinus carpio*

The diet of *C. carpio* varies between juveniles and adult, with juveniles consuming more plankton and larger carp consuming more bottom-dwelling food (Rahman *et al.,* 2015). According to Jinan *et al.,* 2016 larvae of *C. carpio* feed on yolk sac after hatching and shift to free feeding mostly on phytoplankton and diatoms and then after 2-3 weeks from hatching with the increased mouth width, the larvae can fed on zooplankton. Algae, diatoms and copepods were recorded in the digestive canal of both Adult and larvae of common carp in which recorded copepods in the intestines of larvae was less (Jinan *et al.,* 2016). Rahman *et al.,* (2009) reported that larger common carp avoid zooplankton and focus on benthic macroinvertebrates, while little carp preferentially graze on zooplankton (Kasumyan *et al*., 2024). This pattern is in line with ecomorphological research that demonstrates that, as common carp size increases, their ability to retain algae and zooplankton through the branchial sieve decreases (Rahman *et al.,* (2009). Zooplankton and benthic macroinvertebrates were the main food sources for common carp, which ranged in size from 9.5 to 25.9cm TL, and the proportion of benthic macroinvertebrates consumed by common carp increased overall as fish size grew, but the amount of zooplankton ingested dropped (Rahman *et al.*, 2009).

According to Abebe Tesfaye *et al. (*2020), adult common carp was reported to feed on variety of food items including detritus, phytoplankton, macrophytes, ostracods, gastropods, nematodes and benthic aquatic invertebrates whereas juveniles are feeding on zooplankton, insect larvae and ostracods and additionally it is reported that the eggs of other fishes were identified in the diet of adult common carp from Lake Ziway.

CHAPTER 3. MATERIAL AND METHODOLOGY

3.1. The study area

The study was carried out in Gurage drainage basins, namely in Lake Arekit. The Lake situated in Ethiopia, ranges from 2820 to 2950 meters above sea level. Its coordinates are 370°53'30" to 380°10'00" E and 70°59'30" to 80°16'00" N. This 130-hectare lake, with an average depth of 2.5 meters, is depicted in Figure 1 (Yirga Enawgaw and Solomon Wagaw, 2023b). Located in the Central Ethiopia Regional State, it is 220 km from Addis Ababa and 70km from Wolkite the capital city of Gurage zone. The Lake Fed by rainfall and water from nearby watersheds, Lake Arekit, without an outflow, sustains phytoplankton such as Cyanophyta and Bacillariophyta species (Yirga Enawgaw and Solomon Wagaw, 2023a), along with common carp (*Cyprinus carpio*) (Solomon Wagaw *et al*., 2024a and b). The lake is also a habitat for various avifaunas, including endemic species like the Wattled Ibis (*Bostrychia carunculata*) and Blue-Winged Goose (*Cyanochen cyanoptera*) (Belete Tilahun *et al.*, 2022).

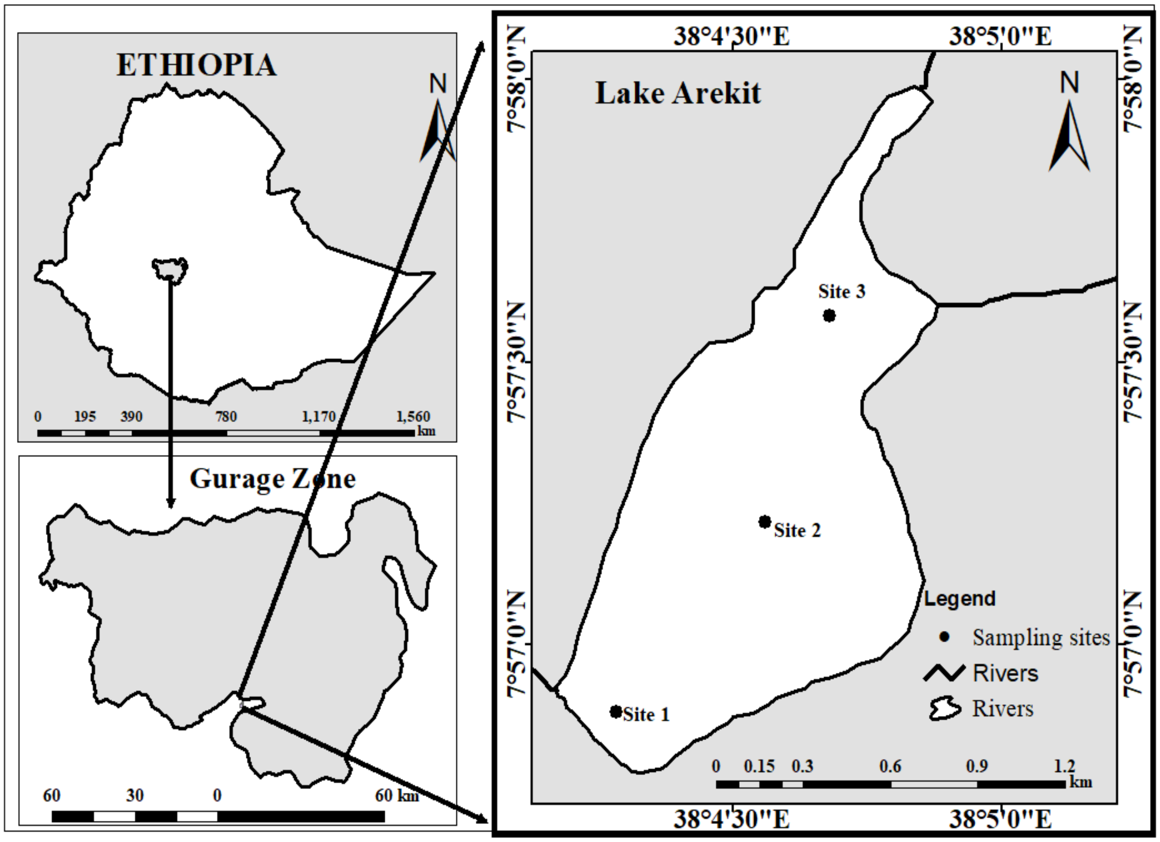


Figure 2: Map of the study area showing the sample stations (Lake Arekit, Ethiopia).

3.2. Sampling and measurement of specimens

During the dry season (February–April 2023) and the wet season (June–August 2023), specimens of *C. carpio* were collected from three lake sampling sites by the fishermen. The mesh sizes of the nets used were 6, 8, 10, and 12cm. Gillnets were set up in the late afternoon (5:00 p.m.) and checked early the following morning (6:00 a.m.). Upon capture, each specimen's total length and weight were determined using a measuring board and weight balance, with precision to within 0.1cm and 0.1g, respectively. The non-empty insides of the fish sample were preserved in a 5% formaldehyde solution for further analysis at Wolkite University.

3.3. Diet composition and feeding habits

The contents of each gut were placed on a Petridish for microscopic identification; larger food items were identified visually, while smaller food categories were identified under compound microscopes using identification keys (Moisan, 2010).

3.4. Gut content analysis

The relative importance of each prey type in the total food content of the gut was studied based on the percentage frequency of occurrence (%Q), percentage volumetric contribution (%V), and index of preponderance (Assis, 1996). In terms of frequency of occurrence, each food item's gut count is recorded and presented as a percentage of the total number of fish stomachs examined. The significance is deduced from the percentage of total guts containing each food item (Buckland *et al.* 2017). Also, the percentage volume contribution of each food item is visually assessed relative to all of the food items present in the gut.

The frequency of occurrence was computed as:

$$\%\ \mathrm{Qi} = \frac{Ji}{P}\ x\ 100$$

Where: % Qi is the frequency of occurrence of given food ‘i’; Ji is the number of guts containing prey ‘i’; P is the total number of guts with some food.

The volumetric measurement (%Vi) was estimated as:

$$\%\ \mathrm{Vi} = \frac{Vi}{Vt}\ x\ 100$$

Where: %Vi is the percentage of volume of given food ‘i’; Vi is the volume of food item ‘i’ present in all specimens; Vt is the total volume of all food items in all specimens

3.5. Food analysis indices

The significance of each food item in the fish gut was evaluated using the Index of Preponderance (IOP) approach which was calculated as described by Tomojiri *et al*. (2019):

$$\text{IOP} = \frac{\%Qi \ \times \%Vi}{\sum_i^s (Qi \ \times \%Vi)} \ x \ 100$$

Where S is the number of prey types, %Qi is the percentage of the frequency of occurrence of species i, and %Vi is the percent composition by volume of species i. To enable comparisons among species, IOPa was converted into percent IOPa (%IOPa).

Additionally, to assess the relative significance of food items and species-level dietary variations, the Geometric Index of Importance (GIIi) (Assis, 1996) was calculated as:

$$\text{GIIi} = \frac{(\sum RMPQi)}{(\sqrt{n})}$$

Where RMPQi is the percentage of volume and frequency of occurrence (as a percentage of total occurrences) and n is the total number of RMPQ parameters used to generate GIIi. The GIIi index treats each dietary metric equally, in which some prey items were better represented by %N (e.g., smaller but countable prey), whereas others were better represented by %V (e.g., fish and other larger prey).

3.6. Seasonal and ontogenetic changes in diet

Diet composition and feeding habits were studied in *C. carpio* across six size classes (< 15cm, 15.1–22cm, 22.1–29cm, 29.1–37cm, 37.1-45cm, and >45cm TL) and two seasons (dry and wet).

3.7. Data Analysis

The data were presented using descriptive statistics (mean, SD, and percentage). ANOVA with Tukey's HSD analysis ($p = 0.05$) was utilized to compare each food item in the diet to other food items within the same size class. The volumetric contributions of the various food categories during the dry and wet seasons are computed by students'-test at a 95% confidence level. All required analysis and computations were conducted using Microsoft Excel 2007 and the ANOVA of SPSS).

CHAPTER 4. RESULTS

4.1. Diet composition

During the study, between 8.8 and 51.3cm in total length (TL), or 16.99 and 2,498.3g in total weight (TW), the fish exhibited varying sizes and weights. After examining the gut contents of 209 fish specimens, it was observed that 174 (83.3%) had stomachs containing food while 35 (16.7%) were empty guts. The 34 food items discovered were classified into seven main groups: nematodes, ostracods, macrophytes, insects, zooplankton, phytoplankton, and detritus (Table 1).

Table 1**:** Various prey categories identified in the stomach contents of *C. carpio* in Lake Arekit, (2023) N= 174)

Detritus	**Insects**	**Zooplankton**	**Phytoplankton**	
Macrophyte	**Dipterans** (Chironomidae)	**Cladocera**	**Diatom**	**Blue-green Algae**
Ostracod	**Coleoptera**	*Daphnia* sp.	*Melosira* sp	*Anabaena* sp.
Nematode		*Diaphanosoma* sp.	*Gomphonema* sp.	*Microcystis* sp.
		Copepod	*Fragilaria* sp.	*Oscillatoria* sp.
		Mesocyclops sp.	*Cymbella* sp.	**Green Algae**
		Thermocyclops sp.	*Cyclotella* sp.	*Merismopedia* sp.
		Rotifer	*Navicula* sp.	*Pediastrum* sp.
		Brachionus sp.	*Nitzschia* sp.	*Scenedesmus* sp.
		Filinia sp.	*Pinnularia* sp	*Ankistrodesmus* sp.
		Trichocerca sp.	*Frustulia* sp	**Euglenoid**
			Epithemia sp.	*Euglena* sp.
			Encynonema sp.	
			Gyrosigma sp.	
			Encyonopsis sp.	

4.2. Qualitative gut content analysis

Table 2 shows the frequency and volumetric contribution of various foods in *C. carpio*. Detritus, making up 33.1% by volume, is the primary component of the carp's diet, being consumed most frequently at 94.8%. In contrast, macrophytes contribute less by volume at 19.8% but rank second in frequency at 66.7%. Insects, found in almost half of the examined stomachs (47.1%), constitute a significant portion (24.7%) of the gut contents.

The most consumed insect group is Diptera (Chironomidae), at 40.8% frequency and 17.8% volume, followed by Coleoptera. Zooplankton, comprising 75.3% of carps' diet, has a modest volume contribution of 11.8%. Cladocerans are more prevalent than copepods and rotifers among zooplankton. Additionally, phytoplankton (5.4%), ostracods (3.5%), and nematodes (2.3%) constitute a small portion of *C. carpio*'s diet in Lake Arekit. Detritus is the main food source for *C. carpio*, with macrophytes following closely. Insects and zooplankton make up around 16.4% and 12.5% of its diet, respectively. Other food categories are eaten in small quantities with low IOP values (Table 3).

Table 2: Diet composition of *C. carpio* in Lake Arekit expressed as: frequency of occurrence and volumetric contribution (2023)

Food items	Frequency of occurrence		Volumetric analysis	
	Number	Percentage %	Volume (ml)	Percentage %
Detritus	165	94.8	129.6	33.1
Macrophyte	116	66.7	77.5	19.8
Insect	82	47.1	96.7	24.7
Diptera	71	40.8	67.3	17.8
Coleoptera	37	21.3	29.4	7.5
Zooplankton	131	75.3	43.8	11.8
Cladocera	54	31.0	22.9	5.8
Copepod	83	47.7	13.2	3.4
Rotifer	97	55.7	7.7	2.0
Phytoplankton	142	81.6	21.2	5.4
Diatom	126	72.4	5.2	1.3
Blue green algae	104	59.8	9.2	2.3
Green algae	81	46.6	4.5	1.1
Euglenoids	62	35.6	2.3	0.6
Ostracods	41	23.6	13.7	3.5
Nematodes	36	20.7	9.1	2.3

Table 3: Index of Preponderance of various food items of gut contents of *C. carpio* in Lake Arekit (2023)

Food items				**Index of Preponderance**
	% of occurrence ($\%Q_i$)	% of volume ($\%V_i$)	$\%Q_i \times \%V_i$	$\text{IOPi} = \frac{\%Qi \times \%Vi}{\sum_i^s(\%Qi \times \%Vi)} x\ 100$
Detritus	94.8	33.1	3137.9	44.3
Macrophyte	66.7	19.8	1320.7	18.6
Insects	47.1	24.7	1163.4	16.4
Zooplankton	75.3	11.8	888.5	12.5
Phytoplankton	81.6	5.4	440.6	6.2
Ostracods	23.6	3.5	82.6	1.2
Nematodes	20.7	2.3	47.6	0.7

Based on the geometric importance index value (%GIIi), detritus accounted for 44.3% of *C. carpio*'s diet, establishing it as the key food source. Insects (%GIIi =16.4), zooplankton (%GIIi =12.5), and macrophytes (%GIIi = 18.6) followed closely (Table 4, Figure 2). Additionally, *C. carpio* occasionally consumed nematodes, ostracods, and phytoplankton in Lake Arekit.

Table 4: Feeding composition and classification of prey according to the geometric importance index value (%GIIi) of *C. carpio* in Lake Arekit (2023)

Food items				**Geometric Index of Importance (GIIi)**		
	Occurrence (Q_i)	% of volume ($\%V_i$)	RMPQi = (%Vi × Qi)	$GIIi = \frac{(\sum RMPQi)}{(\sqrt{n})}$	% GIIi	Grade
Detritus	165	33.1	5461.5	2064.3	44.3	I
Macrophyte	116	19.8	2296.8	868.1	18.6	II
Insect	82	24.7	2025.4	765.5	16.4	III
Zooplankton	131	11.8	1545.8	584.3	12.5	IV
Phytoplankton	142	5.4	766.8	289.8	6.2	V
Ostracods	41	3.5	143.5	54.2	1.2	VI
Nematodes	36	2.3	82.8	31.3	0.7	VII

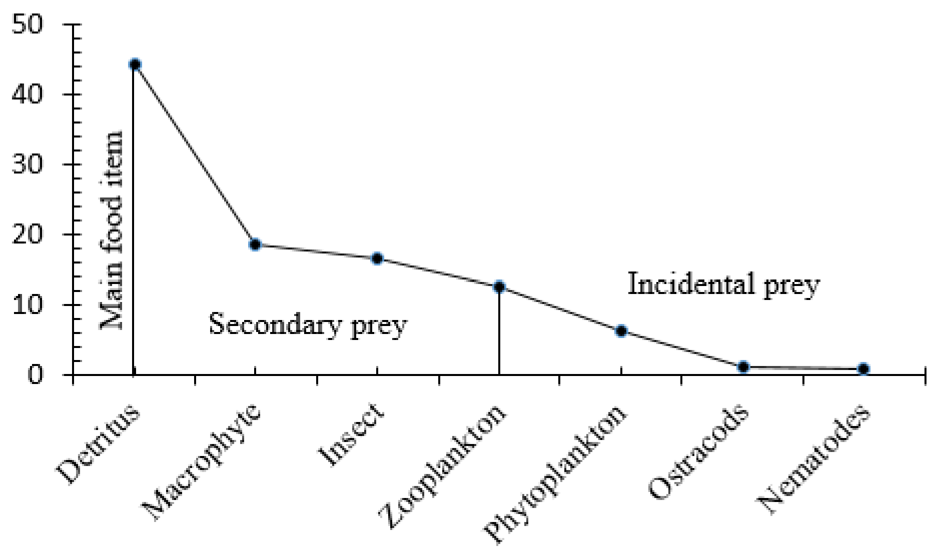


Figure 3: The relative geometric index importance (%GIIi) in the diet of *C. carpio* from Lake Arekit, Ethiopia.

4.3. Seasonal variations in dietary of *C. carpio* in Lake Arekit

Table 5 displays seasonal changes in the food composition of *C. carpio* during the wet and dry seasons, as per a hypothetical statistical analysis ($p < 0.05$). During wet seasons, *C. carpio* seems to consume a greater amount of food items than in dry seasons (Table 5). Nonetheless, the volumetric contribution per fish shows a statistically significant trend student's t-test applied at ($p < 0.05$) for all food components except ostracods and nematodes.

Table 5: Seasonal variations of the relative volumetric contribution of food items to individual *C. carpio* in Lake Arekit (2023)

Seasons	Phytoplankton	Zooplankton	Insects	Ostracods	Nematodes	Detritus	Macrophytes
Dry	0.42 ± 0.26^{a}	0.79 ± 0.32^{a}	2.10 ± 1.20^{a}	0.27 ± 0.32^{a}	0.19 ± 0.18^{a}	2.92 ± 2.57^{a}	1.34 ± 1.18^{a}
Wet	0.76 ± 0.41^{b}	1.64 ± 0.60^{b}	3.27 ± 1.70^{b}	0.50 ± 0.56^{a}	0.32 ± 0.27^{a}	4.28 ± 3.39^{b}	2.96 ± 2.62^{b}

Seasonal variations of food items are detailed in Table 6, indicating the Index of Preponderance (%IOP) for each. Macrophytes showed notably high IOP values in the wet season at 24.0%, contrasting with 12.8% in the dry season. Zooplankton (%IOP = 13.0), phytoplankton (%IOP = 6.6), ostracods (%IOP = 1.3), and nematodes (%IOP = 0.8) were present in dry seasons. Insects, on the other hand, were a significant food source in the dry season at 21.4%, but their importance dropped to 12.7% in the wet season (Table 6).

Table 6: Seasonal diet composition of *C. carpio* in Lake Arekit (2023).

Food items	%Q_i		%V_i		%IOP	
	Dry	Wet	Dry	Wet	Dry	Wet
Detritus	89.9	98.9	36.4	31.2	44.1	45.9
Macrophyte	57	74.7	16.7	21.6	12.8	24.0
Insect	60.8	35.8	26.2	23.8	21.4	12.7
Zooplankton	98.7	55.8	9.8	12	13.0	10.0
Phytoplankton	93.7	71.6	5.2	5.5	6.6	5.9
Ostracods	29.1	18.9	3.3	3.6	1.3	1.0
Nematodes	25.3	16.8	2.4	2.3	0.8	0.6

N.B. Expression: %Qi – percentage of frequency of occurrence; %Vi – percentage of volumetric contribution; %IOP – Index of Preponderance.

4.4. Ontogenetic dietary shift in feeding habits of *C. carpio*

Table 7 and Figure 3 indicate statistically significant variances ($p < 0.05$) in the consumption of various food items among size classes and changes in feeding patterns as fish mature. Animal origin foods like zooplankton, insects, and ostracods were prominent in diets of smaller size classes but decreased as fish size increased (Table 7; Figure 3). In the largest size class (> 22.1 cm TL), detritus and macrophytes were the main components, with other food items being negligible (Figure 3). The volume contribution of different food items in the diet of individual *C. carpio* within each size class range is shown in Table 7, and a significant difference was detected in the volume contribution of food items within the same size class (ANOVA, $p < 0.05$).

Consumption of detritus and macrophytes increases with size (a significant difference compared to most other items). Conversely, consumption of zooplankton, insects, ostracods, and nematodes shows a clear decrease with increasing size class, while consumption of phytoplankton displays a more intricate pattern. Although phytoplankton is a minor component throughout the carp's life, a notable increase is observed in mid-sized carp (29.1–37cm) (Figure 3).

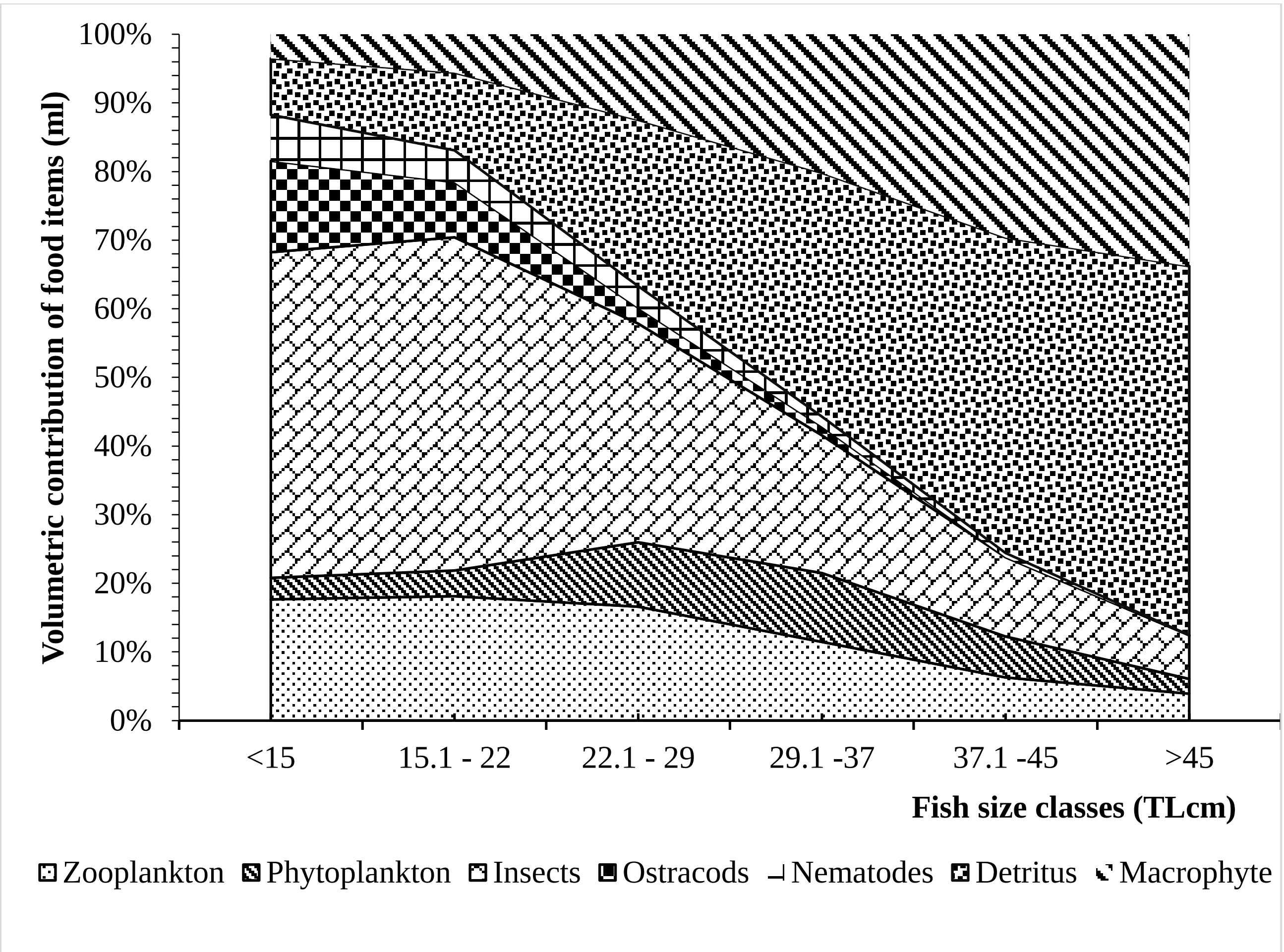


Figure 4: Ontogenetic dietary shift of *C. carpio* in Lake Arekit, Ethiopia

Table 7: Feeding preferences of *C. carpio* in Lake Arekit across different size classes (2023).

Size class	**Phytoplankton**	**Zooplankton**	**Insects**	**Ostracods**	**Nematodes**	**Detritus**	**Macrophytes**
<15cm	0.27±0.13^{c}	1.50±0.56^{ab}	4.03±0.86^{a}	1.33±0.38^{a}	0.57±0.19^{a}	0.70±0.19^{d}	0.30±0.13^{c}
15.1–22 cm	0.38±0.14^{bc}	1.83±0.73^{a}	4.92±1.11^{a}	0.82±0.29^{a}	0.47±0.19^{ab}	1.15±0.31^{d}	0.57±0.29^{c}
22.1–29 cm	0.80±0.35^{ab}	1.42±0.59^{ab}	2.72±0.74^{b}	0.20±0.07^{b}	0.27±0.10^{bc}	2.07±0.65^{cd}	1.07±0.48^{c}
30.1–37 cm	1.05±0.44^{a}	1.2±0.49^{ab}	2.10±0.57^{bc}	0.13±0.05^{b}	0.15±0.05^{cd}	3.72±1.14^{bc}	2.12±0.93^{bc}
38.1–45 cm	0.68±0.29^{abc}	0.72±0.30^{b}	1.32±0.37^{c}	0.00±0.00^{b}	0.07±0.02^{cd}	5.25±1.58^{b}	3.38±1.45^{ab}
>45 cm	0.35±0.16^{bc}	0.63±0.27^{b}	1.03±0.36^{c}	0.00±0.00^{b}	0.00±0.00^{d}	8.72±2.40^{a}	5.48±2.43^{a}

Note. Values with different letters (a, b, c, d) within a column are significantly different at $p < 0.05$ level (Tukey's test is applied).

CHAPTER 5. DISCUSSION

5.1. Diet composition and feeding habits of *C. carpio* in Lake Arekit

An investigation into stomach content analysis is crucial for yielding taxonomic data on fish diets and their ecological roles (Manko, 2016), as well as for developing models for stock assessment and supplying insights into the maintenance (replenishing) of overfished species in the context of monopoly culture systems (Sivadas and Bhaskaran, 2009). For optimal use of the stock in Lake Arekit, it is crucial to investigate the feeding biology of *C. carpio*, one of the commercially significant fish species in Ethiopia.

The diet composition of *C. carpio* in the present study includes detritus, macrophytes, insects, zooplankton, phytoplankton and aquatic worms. In other study according to evidence accessible elsewhere (Rahman *et al.*, 2006; Saikia and Das, 2008), *C. carpio* was shown to have an omnivorous feeding habits, that feeds on a variety of food items, including macrophytes, algae, detritus, diatoms, debris, mud, insects, zooplankton, crustaceans, and nematodes (Elias Dadebo *et al*., 2015), and detritus is the main component of their diet (Abebe Tesfaye *et al*., 2020). In similar in Lake Arekit, detritus makes up 33.1% of their overall food consumption, while macrophytes, insects, and zooplankton are also significant food sources.

Their gut content analysis categorizes them as detri-omnivores, supporting their feeding behavior close to the bottom, as indicated by the presence of benthic organisms like nematodes, insect larvae (Chironomideae), and ostracods in their gut. Khelifi *et al*. (2017) have also labelled *C. carpio* as benthophagous, showing a preference for benthic organisms. Similarly detri-omnivore feeding behaviors of *C. carpio* have been noted in Lake Dal (Naik *et al*., 2015) and Lake Ziway (Abebe Tesfaye *et al*., 2020).

Moreover other studies have highlighted the omnivorous feeding tendencies of *C. carpio* at Foum ElKhanga Dam (Saikia and Das, 2008); (Sahtout *et al*., 2018) discovered that algae, zooplankton (Cladocera, Copepoda, Rotifera), benthic creatures (Diptera, primarily Chironomidae larvae), plant residues, and mud make up the majority of the gastrointestinal contents of *C. carpio* in Indian lakes. Lanzoni, (2020)**,** discovered mud, phytoplankton, zooplankton, and debris in the digestive system of *C. carpio* in River Delta.

Also in Ethiopian water bodies Such as in Lake Koka (Elias Dadebo *et al*., 2015), *C. carpio* consume detritus, insects, macrophytes, phytoplankton, ostracods, zooplankton, and gastropods, with plant and animal matter being their primary prey items. In Lake Ziway it was reported that common carp feeds on a variety of food items (macrophytes, detritus, insects, Phytoplankton, zooplankton, nematodes, ostracods, gastropods and unidentified animals) and it can thus be considered as polyphagous (Abebe Tesfaye, 2018).

Food item preferences are indicated by the Index of Preponderance (%IOP). The current study results reveal detritus as the most preferred food item, followed by macrophytes and insects. Previous research has also highlighted the significant role of detritus in the diet of *C. carpio* (Elias Dadebo *et al*., 2015; Naik *et al*., 2015; Sahtout *et al*., 2018; Abebe Tesfaye *et al*., 2020). This suggests the species-wide adaptability of the benthic habitat in Lake Arekit. The prominence of detritus in the diet of carp species could be linked to their habitat preference, given their bottom-dwelling nature (Mishra, 2020). Moreover, detritus, a decaying organic material teeming with microorganisms such as bacteria and decomposers, is abundant in most aquatic environments, rendering it a convenient and dependable food source (Abebe Tesfaye *et al*., 2020; Solomon Wagaw *et al*., 2022).

An examination of the geometric index of importance (%GIIi) (Table 4, Figure 2) regarding food and feeding habits revealed that 44.3% of the gut contents of *C. carpio* were composed of detritus. Nikolskii (1963) in Shafi *et al*. (2012) categorized fish food into three groups based on its importance in the fish diet: (a) primary food, typically consumed by the fish and making up a significant portion of the diet; (b) secondary food, frequently found in the stomach but in smaller amounts; and (c) incidental food, seldom detected in the gut.

According to Nikolskii's (1963) classification, detritus acts as the main or primary food for *C. carpio* in Lake Arekit, while macrophytes, zooplankton, and insects constitute its secondary food sources; and phytoplankton, nematodes, and ostracods are considered incidental food items. These findings are consistent with research on *C. carpio* carried out by Elias Dadebo *et al*. (2015) and Abebe Tesfaye *et al*. (2020) in Lake Koca and Ziway, respectively. The similarity in preference of having a high proportion of detritus in their diet in these lakes may be resulted from their living style on the bottom of the lakes.

In contrast, Shafi *et al*. (2012) identified arthropods and macrophytes as the main food sources, while oligochaetes, protozoans, rotifers, and algae were classified as secondary food sources and molluscan and fish parts were labeled as incidental food for *C. carpio* in Lake Dal, Kashmir, India. The difference may resulted from the nature of the lakes in which Lake Dal may lacks inflow water bodies that bring out decomposed materials to make detritus preferable while those comparable lakes have inflows to increasing detritus availability.

5.2. Seasonal variations in diet of *C. carpio* in Lake Arekit

The results of the current study confirm that the preponderance index (%IOP) of each food item significantly varies by season. Seasonality seems to be a crucial factor influencing the food habits of carp in Lake Arekit. The highest volumetric contribution percentage is observed during the wet season, decreasing during the dry season. These findings are similar with that of Elias Dadebo *et al*. (2015) and Abebe Tesfaye *et al*. (2020), who reported a high detritus and macrophyte contribution during the wet season. In Lake Arekit, *C*. *carpio* consumed more detritus and insects in the dry season, while detritus and macrophytes remained significant during the wet season, with insects also becoming a notable food source.

The highest volume of detritus in wet season could be due to the fact that large quantities of plant materials and debris may be carried into the lake by runoff during the rainy months and create a larger load of sediments. The highest volume of macrophytes in wet season may be due to the fact that they grow highly in rainy season in Lake Arekit. In other hand the highest availability of insects during dry season may be resulted from the highest transparency and its availability to insects' reproduction in dry season while its high turbidity may avoids the insects' reproduction and abundance in wet season. The high contribution of detritus in wet months is also in agreement with the report by Shukla *et al.* (2013) who stated that the organisms which could not be defined (detritus) were most frequently observed in wet season in Lake Rewa, India.

Similarly, Elias Dadebo *et al.* (2015) reported that volumetric contribution of detritus was high in wet months in Lake Koka, Ethiopia. The similarity in detritus preference in these lakes may be because of the selective feeding habit of *C. carpio* on easily available detritus rather than searching for other food types.

Different studies have indicated notable variations in *C. carpio* feeding habits based on diet and seasonal patterns between dry and wet seasons (Khelifi *et al*., 2017; Sahtout *et al*., 2018; Abebe Tesfaye *et al*., 2020). These differences in *C. carpio* feeding behaviors are linked to factors such as food availability, spawning period, and environmental conditions (Solomon Wagaw *et al*., 2022). Researches have also emphasized the adaptability of *C. carpio*'s feeding habits (Sahtout *et al*., 2018; Berrouk *et al*., 2022) and reported that they are opportunistic omnivores, consuming diverse food items based on natural resources, seasons, age, length, and weight (Elias Dadebo *et al*., 2015; Abebe Tesfaye *et al*., 2020).

5.3. Ontogenetic dietary shifts in *C. carpio* in Lake Arekit

Different researches indicate that *C. carpio* is a versatile feeder, showing flexibility in foraging habits (Sahtout *et al*., 2018; Yang *et al*., 2018; Abebe Tesfaye *et al*., 2020). In Lake Arekit, competition for food within the species decreases due to a significant change in dietary preferences as they grow. Young fish primarily feed on insects, zooplankton, and ostracods, while larger *C. carpio* prefers detritus and macrophytes. Studies have observed an increase in detritus and macrophyte consumption as fish grow older and larger, correlating with the elongation of their intestines (Khelifi *et al*., 2017).

In other hand due to their bottom dwelling lifestyle, larger common carp may have a high concentration of detritus in their diet (Abebe Tesfaye *et al*., 2020). Ontogenetic dietary shift is also seen in *C. carpio* (Sahtout *et al*., 2018; Abebe Tesfaye *et al*., 2020), with these dietary shifts influenced by the energy expenditure of acquiring food, metabolic processes, physiological changes, digestive system maturation, habitat preferences, and age related behaviors (Khelifi *et al*., 2017; Sahtout *et al*., 2018; Abebe Tesfaye *et al*., 2020; Solomon Wagaw *et al*., 2022).

Another reason for why smaller fish may feed on zooplankton and insect larvae is that, because of their higher specific growth rate and greater mass specific metabolism, smaller fish may have a higher mass protein demand than what they can get from a plant-based diet (Benavides *et al.*, 1994). Thus, smaller fish tend to feed more on animal based foods and change to more plant based foods as they grow as smaller fish may not be able to eat large macrophytes and debris due to their tiny gut volumes.

The other most likely explanation for why smaller fish eat more zooplankton and insects is that food items with an animal origin are more easily digested, making smaller fish prefer zooplankton and insects. The greater proportion of insects in the diet of small sized common carp may also be explained by the smaller fish's habitat requirements in the shallow littoral areas where these invertebrates are abundant to use macrophytes as cover from predators that makes them available to be eaten by smaller fish (Abebe Tesfaye *et al.,* 2020).

Generally, studies revealed an ontogenetic nutritional shift in which larger fish mostly ingested detritus, macrophytes, and phytoplankton, whereas smaller fish placed a greater emphasis on insects and zooplankton and as a result, consumption of food originating from plants increased with fish size whereas that of food originating from animals decreased (Abebe Tesfaye *et al.*, 2020).

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The diet of *C. carpio* in Lake Arekit is characterized by a high reliance on detritus, which constitutes the largest portion of its diet by both frequency and volumetric contribution. This finding aligns with previous studies indicating that *C. carpio* is a detritivore-omnivore, with detritus, macrophytes, and insects forming the primary components of its diet. The dietary composition of *C. carpio* in Lake Arekit reflects its benthic feeding behavior, as evidenced by the substantial intake of detritus and benthic organisms such as nematodes and insect larvae.

Seasonal variations in diet reveal that *C. carpio* in Lake Arekit exhibits flexibility in its feeding habits. During the wet season, there is a notable increase in the consumption of macrophytes and detritus, likely due to the influx of organic material and increased availability of plant matter. Conversely, in the dry season, the consumption of insects and detritus increases, possibly influenced by the decreased availability of other food sources and changes in the lake's turbidity and food availability.

Ontogenetic shifts in feeding habits are evident, with younger fish preferring animal-based foods such as zooplankton and insects, while older, larger fish consume more detritus and macrophytes. This shift reflects changes in digestive physiology and habitat use as *C. carpio* matures, with larger individuals likely adopting a more benthic feeding strategy in Lake Arekit.

6.2. Recommendations

This study on the diet composition, feeding habits, and seasonal and ontogenetic dietary shifts of *Cyprinus carpio* (Linnaeus 1758) in Lake Arekit, Ethiopia, offers the following recommendations for fisheries management and conservation:

1. **Management and Conservation:**
   - ✓ Habitat Management: To support the detritus-based diet of *C. carpio*, maintain and enhance the availability of organic detritus in Lake Arekit through minimizing disturbances that might reduce detrital inputs, such as shoreline development and excessive dredging.
   - ✓ Macrophyte Protection: Preserve aquatic macrophyte habitats, especially in the wet season, to support the dietary needs of *C. carpio* in Lake Arekit.
2. **Seasonal Monitoring:**
   - ✓ Food Availability Studies: Conduct regular monitoring of food availability and composition in different seasons to understand how changes in environmental conditions affect the diet of *C. carpio* in Lake Arekit.
3. **Research and Data Collection:**
   - ✓ Dietary Shifts Analysis: Further investigate ontogenetic dietary shifts and their ecological implications that can inform strategies to support different life stages of *C. carpio* in Lake Arekit effectively.
4. **Public Awareness and Stakeholder Engagement:**
   - ✓ Community Education: Educate local communities and stakeholders about the ecological role of *C. carpio* in Lake Arekit and the importance of maintaining healthy aquatic habitats and engaging stakeholders in conservation efforts can lead to better protection and management of lake ecosystems.

By implementing these recommendations, it is possible to support the sustainable management of *C. carpio* populations and maintain the ecological balance in Lake Arekit, Ethiopia.

REFERENCES

Abdel-Hamid, E. A., Gharib, A. A., Mousa, M. A., and Naiel, M. A. (2022). Improving water quality, growth performance, and modulating some stress physiological biomarkers in *Cyprinus carpio* using raw date nuclei as a zinc adsorbent agent. *Applied Water Science*, ***12*** (**7**), 1-9.

Abebe Tesfaye, Abebe Getahun, and Tadesse Fetahi, (2020). Food and feeding habits of the juvenile and adult Common carp (*Cyprinus carpio*) in Lake Ziway, Ethiopia. *SINET: Ethiopian Journal of Science*, ***43*** (**2**), 77-87.

Abo-Taleb, H. A., El-Tabakh, M. A., and Hendy, D. M. (2023). Plankton and fish nutrition in African lakes. In *Lakes of Africa* (pp. 139-172), Elsevier.

Alieva, A. K., Nasibulina, B. M., Bakhshalizadeh, S., Kurochkina, T. F., Popov, N. N., Barbol, B. I., and Ali, A. M. (2023). The Low Ontogenetic Diet Diversity and Flexibility of the Pike-Perch, *Sander lucioperca* (Linnaeus, 1758) (Osteichthyes, Percidae): A Case Study. *Fishes*, **8** (**8**), 395.

Al-Lamy, H. J., and Taher, M. M. (2016). Food and feeding habits of common carp (*Cyprinus carpio)* larvae and juveniles in earthen ponds. *Basrah J Agri Sci*, **29** (**1**), 17-24.

Assefa Tessema, Abebe Getahun, Seyoum Mengistou, Tadesse Fetahi, and Eshete Dejen, (2020). Reproductive biology of common carp (*Cyprinus carpio* Linnaeus, 1758) in Lake Hayq, Ethiopia. *Fisheries and Aquatic Sciences*, **23** (**1**), 1-10.

Assis, C. A. (1996). A generalized index for stomach contents analysis in fish. *Scientia Marina*, 60(2), 385-389.

Belete Tilahun, Abebe Hailu, Kassahun Abie, Teklebrehan Kidane, and Asmeraw Alemkere, (2022). Avifauna diversity and conservation challenges in Lake Arekit, Southern Ethiopia. *Israel Journal of Ecology and Evolution*, **68** (1-4), 74-83.

Berrouk, H., Sid, A., Lahoual, A., Sahtout, F., Kaouachi, N., and Boualleg, C. (2022). Effect of parasitic copepods on the length-weight relationship and the condition factor of crucian carp (*Carassius carassius*) in the Beni-Haroun Dam, Mila City, Northeast Algeria. *Animal Research International*, **19** (**3**), 4625-4633.

Bressman, N. R. (2022). Terrestrial capabilities of invasive fishes and their management implications. *Integrative and Comparative Biology*, **62** (**5**), 1377-1394.

Buckland, A., Baker, R., Loneragan, N., and Sheaves, M. (2017). Standardizing fish stomach content analysis: The importance of prey condition. *Fisheries Research*, 196, 126-140.

Cooke, S. J., Cech, J. J., Glassman, D. M., Simard, J., Louttit, S., Lennox, R. J., and O'Connor, C. M. (2020). Water resource development and sturgeon (Acipenseridae): State of the science and research gaps related to fish passage, entrainment, impingement and behavioural guidance. *Reviews in Fish Biology and Fisheries*, *30*, 219-244.

Diana, J. S., and Hook, T. O. (2023). *Biology and ecology of fishes*. John Wiley and Sons.

Dou, H., Wang, M., Yin, X., Feng, L., and Yang, H. (2023). Can the Eurasian otter (*Lutra lutra*) be used as an effective sampler of fish diversity? Using molecular assessment of otter diet to survey fish communities. *Metabarcoding and Metagenomics*, **7**, e96733.

Elias Dadebo, Alamrew Eyayu, Solomon Sorsa, and Girma Tilahun, (2015). Food and feeding habits of the common carp (*Cyprinus carpio* L. 1758) (Pisces: Cyprinidae) in Lake Koka, Ethiopia. *Momona Ethiopian Journal of Science*, **7** (**1**), 16-31.

Eljasik, P., Panicz, R., Sobczak, M., and Sadowski, J. (2022). Key performance indicators of common carp (Cyprinus carpio L.) wintering in a pond and RAS under different feeding schemes. *Sustainability*, **14** (**7**), 3724.

Ellender, B. R., Weyl, O. L. F., Shanyengange, M. K., and Cowley, P. D. (2008). Juvenile population dynamics of *Oreochromis mossambicus* in an intermittently open estuary at the limit of its natural distribution. *African Zoology*, **43** (**2**), 277-283.

Endalh Mekonnen, Gedion Berihanu, and Tizazu Yitayew, (2019). Biological aspects, catch and length distribution of African catfish, *Clarias gariepinus* and common carp, *Cyprinus carpio* in in Lake Lugo, south wollo, Ethiopia. *Ethiopian Journal of Science and Technology*, **12** (**3**), 185-202.

Golubtsov, A. S., and Darkov, A. A. (2008). A review of fish diversity in the main drainage systems of Ethiopia based on the data obtained by 2008. In *Ecological and faunistic studies in Ethiopia, Proceedings of jubilee meeting "Joint Ethio-Russian Biological Expedition* (Vol. 20, pp. 69-102). Moscow: *KMK Scientific Press.*

Gul, A. L. I., Yılmaz, M., Kuşçu, A., and Benzer, S. (2010). Feeding properties of common carp *cyprinus carpio* l., 1758 living in Hirfanli dam LAKE. *Kastamonu Education Journal*, **18** (**2**), 545-556.

Hanel, L. U. B. O. M. Í. R., Plesník, J., Andreska, J., Lusk, S., Novak, J., and Plíštil, J. (2011). Alien fishes in European waters. *Bulletin Lampetra*, **7**, 148-185.

Hassan, M., Shah Norhan, N. A., Mohd Daud, H., Chong, J. L., Abd Halim Shah, M. M., and Karim, N. U. (2015). Behavioral and histopathological changes of common Carp (*Cyprinus carpio*) exposed to paraquat. *J Fish Livestock Product*, **3**, 1-3.

Hossain, M. A., Haque, M. A., Mondol, M. M. R., Harun-Ur-Rashid, M., and Das, S. K. (2022). Determination of suitable stocking density for good aquaculture practice-based carp fattening in ponds under drought-prone areas of Bangladesh. *Aquaculture*, 547, 73, 74, 85.

Imran, M., Khan, A. M., and Waseem, M. T. (2021). Dietary Overlap between Native and Exotic Fishes revealed through Gut Content Analysis at Head Baloki, Punjab, Pakistan. *Journal of Bioresource Management*, **8** (**1**), 10.

Jinan H. Al-Lamy and Majid M. Taher (2016) Food and Feeding Habits of Common Carp (*Cyprinus carpio*) Larvae and Juveniles in Earthen Ponds *Basrah J. Agric. Sci.,* **29** (**1**): *17-24,2016*

Kang, B., Vitule, J. R., Li, S., Shuai, F., Huang, L., Huang, X., and Lou, F. (2023). Introduction of non-native fish for aquaculture in China: A systematic review. *Reviews in Aquaculture*, **15** (**2**), 676-703.

Kasumyan, A. O., Kuzishchin, K. V., and Gruzdeva, M. A. (2024). Evaluation of the Effectiveness of Food Chemical Attractants for Wild Common Carp, *Cyprinus carpio* (Cyprinidae) under Conditions of Natural Water Body. *Journal of Ichthyology*, **64** (**4**), 689-704.

Kaur, H., and Singh, R. (2010). A new myxosporean species *Myxobolus sclerii* sp. nov., and one known species.

Khelifi, N., Boualleg, C., Sahtout, F., Kaouachi, N., Mouaissia, W. A. H. I. B. A., and Bensouillah, M. (2017). Feeding habits of *Carassius carassius* (Cyprinidae) in Beni Haroun Dam (north-east of Algeria). *Aquaculture*, *Aquarium*, *Conservation and Legislation*, **10** (**6**), 1596-1609.

Koehn, J. D., and S. J. Nicol. "Comparative movements of four large fish species in a lowland river." *Journal of Fish Biology* 88, no. **4** (2016): 1350-1368.

Kwak, Y. H., Kim, S. Y., Go, Y. S., Lee, D. H., Song, H. Y., Chung, S. O., and Choi, B. (2023). Insights into Ontogenetic Niche Changes in Bluegill, *Lepomis macrochirus*, Applying Combined Analyses of Stomach Content and Stable Isotopes. *Water*, **15** (**19**), 3488.

Lanzoni, M. (2020). Status of the fish communities and need for management in the Po River Delta.

Lyach, R. (2022). Fisheries Management of the European Catfish *Silurus glanis* is Strongly Correlated to the Management of Non-Native Fish Species (Common Carp *Cyprinus carpio*, Rainbow Trout *Oncorhynchus mykiss*, and Grass Carp *Ctenopharyngodon idella*). *Sustainability*, **14** (**10**), 6001.

Mangi, A., and Memon, Z. N. (2017). Analysis of gut contents of Common carp *(Cyprinus carpio)* in district Larkana, Sindh, Pakistan. *J. Entomol. Zool. Stud*, **5**, 2631-2634.

Manko, P. (2016). Stomach content analysis in freshwater fish feeding ecology. *University of Presov*, **116** (**5**), 1-25.

Manon, M. R., and Hossain, M. D. (2011). Food and feeding habit of *Cyprinus carpio* var. specularis. *Journal of Science Foundation*, **9** (**1-2**), 163-169.

Maritz, B., Barends, J. M., Mohamed, R., Maritz, R. A., and Alexander, G. J. (2021). Repeated dietary shifts in elapid snakes (Squamata: Elapidae) revealed by ancestral state reconstruction. *Biological Journal of the Linnean Society*, **134** (**4**), 975-986.

Mathewos Temesgen, Abebe Getahun, Brook Lemma, and Janssens, G. P. (2022). Food and feeding biology of Nile tilapia (*Oreochromis niloticus*) in Lake Langeno, Ethiopia. *Sustainability*, **14** (**2**), 974.

Menasria, A., and Bensouilah, M. (2018). Feeding habits of *Cyprinus carpio* in Foum El-Khanga Dam, Souk-Ahras, Algeria. *AACL Bioflux*, **11** (**2**).

Mishra, S. P. (2020). Seasonal variation in gut contents of Indian major carp, *Cirrhinus mrigala* from Meeranpur Lake, *India. Int. J. Biol. Innov*, **2**, 202-208.

Moisan J. (2010). Guide for the identification of principal Quebec's freshwater benthic macro invertebrates, voluntary monitoring of shallow watercourses. *State of the Environment Monitoring Directorate, Ministry of Sustainable Development, Environment and Parks, 82 pp.*

Naik, G., Rashid, M., Balkhi, M. H., and Bhat, F. A. (2015). Food and feeding habits of *Cyprinus carpio* var. *communis*: A reason that decline Schizothoracine fish production from Dal Lake of Kashmir Valley. *Fisheries and Aquaculture Journal*, 6 (4), 1000155.

Nair, R. J., George, G., Ratheesh Kumar, R., Sreenath, K. R., Sreeram, M. P., Padua, S., and Haritha, S. (2024). Training Manual on "Know Your Marine Biodiversity and Environment (MarBiE 2)" *Taxonomy of Marine Organisms.*

Nattabi, J. K. (2018). Aspects of the digestive physiology of larvae of the North African catfish, *Clarias gariepinus* (Burchell 1822), during early development.

Nikolskii, G.V. (1963). The ecology of fishes. London and New York: *Academic Press*, pp. 325.

Oyugi, D. O. (2012). *Ecological impacts of common carp cyprinus carpio L. 1758 (Pisces: cyprinidae)* on natural fish species in Lake Naivasha, *Kenya* (Doctoral dissertation, University of Nairobi, Kenya).

Parkos, J. I. I. I., and Wahl, D. (2014). Effects of common carp (*Cyprinus carpio*), an exotic fish, on Aquatic Ecosystems. Ilinois Natural History Survey report of January/February 2000. University of Illinois Board of Trustees. *Center for Aquatic Ecology*.

Rahman, M. M. (2015). Role of common carp (*Cyprinus carpio*) in aquaculture production systems. *Frontiers in Life Science*, **8** (**4**), 399-410.

Rahman, M. M., Ferdouse, Z., Nur, N., Islam, M. N., Rouf, M. A., Arafat, S. T., and Rahman, M. M. (2022). Microplastic ingestion alters the expression of some sexually selected traits in a model fish guppy (*Poecilia reticulata* Peters 1859). *Marine and Freshwater Behavior and Physiology*, **55** (**3-4**), 87-106.

Rahman, M. M., Hossain, M. Y., Jo, Q., Kim, S. K., Ohtomi, J., and Meyer, C. (2009). Ontogenetic shift in dietary preference and low dietary overlap in rohu (*Labeo rohita*) and common carp (*Cyprinus carpio*) in semi-intensive polyculture ponds. *Ichthyological research*, 56, 28-36.

Rahman, M.M., Nagelkerke, L.A., Wahab, M.A., Milstein, A. and Verreth, J. (2006). Growth, production and food preference of rohu *Labeo rohita* (H.) in monoculture and polyculture with common carp *Cyprinus carpio* (L. 1758) under fed and non-fed ponds. *Aquaculture*, **257**: 359-372

Ramirez-Herrejon, J. P., Moncayo-Estrada, R., Balart, E. F., Camacho, L. G., Rodríguez, B. V., Villanueva, R. A., and Caraveo-Patino, J. (2014). Trophic interrelations between introduced common carp, Cyprinus carpio (*Actinopterygii: Cypriniformes*: Cyprinidae), and fish community in a eutrophic shallow lake. *Actaichthyologica etpiscatoria*, **44** (**1**), 45-58.

Richter, L. M., and Dawes, A. R. (2008). Child abuse in South Africa: rights and wrongs. *Child Abuse Review: Journal of the British Association for the Study and Prevention of Child Abuse and Neglect*, **17** (**2**), 79-93.

Rishikanta, N. S., Das, S. K., Kumar, S., Behera, S., and Nagesh, T. S. (2015). Length-weight relationship and condition factor of *Cyprinus carpio* var. communis (Linnaeus, 1758) reared in bheries of South Parganas district in West Bengal. I. *Journal of Fisheries and Aquatic Studies*, **2** (**6**), 239-242.

Sahtout, F., Boualleg, C., Kaouachi, N., Khélifi, N., Menasria, A., and Bensouilah, M. (2018). Feeding habits of *Cyprinus carpio* in Foum El-Khanga Dam, Souk-Ahras, Algeria. *Aquaculture, Aquarium, Conservation and Legislation*, **11** (**2**), 554-564.

Saikia, S.K. and Das, D.N. (2008). Feeding ecology of common carp in a rice-fish culture system of the Apatani Plateau. *Aquat. Ecol.*, 23: 513-524.

Sarkar, U. K., Sandhya, K. M., Mishal, P., Karnatak, G., Lianthuamluaia, Kumari, S., and Das, B. K. (2018). Status, prospects, threats, and the way forward for sustainable management and enhancement of the tropical Indian reservoir fisheries: an overview. *Reviews in Fisheries Science and Aquaculture*, **26** (**2**), 155-175.

Shafi, S., Bhat, F. A., Yousuf, A. R., and Parveen, M. (2012). Biology of *Cyprinus carpio communis* from Dal Lake, Kashmir with reference to food and feeding habits, length-weight relationship, and fecundity. *Nature, Environment and Pollution Technology*, **11** (**1**), 79-87.

Shoup, D. E., and Wahl, D. H. (2009). The effects of turbidity on prey selection by piscivorous largemouth bass. *Transactions of the American Fisheries Society*, *138*(5), 1018-1027.

Shukla, N. S. and Patel, V. (2013). Studies on Food and Feeding Behavior of Common carp and their gastrosomatic Index from Govindgarh Lake, Rewa (M.P.), *Indian J. Fish.* **45**: 349-353.

Sivadas, M., and Bhaskaran, M. M. (2009). Stomach content analysis of the Indian mackerel Rastrelliger kanagurta (Cuvier) from Calicut, Kerala. *Indian Journal of Fisheries*, **56** (**2**), 143-146.

Solomon Wagaw, Seyoum Mengistou, and Abebe Getahun, (2022). Diet composition and feeding habits of *Oreochromis niloticus* (Linnaeus, 1758) in Lake Shala, Ethiopia. *Fisheries and Aquatic Sciences*, 25 (1), 20-30.

Solomon Wagaw, Yirga Enawgaw, Ahmed Aba Bulgu, Assefa Wosnie, Ayalew Sisay, Ashenafi Teklemariam, and Demeke Tegod, (2024b). Biometric assessment and reproductive biology of common carp (*Cyprinus carpio* var. *communis*) in Lake Arekit, Ethiopia: Fish management implication. *Cogent Food and Agriculture*, **10** (**1**), 2307667.

Solomon Wagaw, Yirga Enawgaw, and Injigu Wendimu, (2024a). Population Dynamics of the Common Carp (*Cyprinus carpio* L. 1758) Stock in Lake Arekit, Ethiopia: Implications for Management and Conservation. *Journal of Applied Ichthyology*, 2024.

Sutradhar, S., Yasmin, F., Roy, A., Sarkar, R., and Mukherjee, S. (2023). Age-related changes in the gut melatonin levels and its possible role in the regulation of feeding and digestibility, with the development of the gut from fingerling to adult stages of carp, *Catla catla*. *Journal of Comparative Physiology B*, **193** (**6**), 647-660.

Tomojiri, D., Musikasinthorn, P., and Iwata, A. (2019). Food habits of three non-native cichlid fishes in the lowermost Chao Phraya River basin, Thailand. *Journal of freshwater ecology*, **34** (**1**), 419-432.

Verma, D. R., Ahmad, T., and Dixit, H. A. V. K. (2020). Studies on the stomach content analysis and feeding ecology of fishes of Rapti River at balrampur disrtict up India.

Weber, M. J., and Brown, M. L. (2009). Effects of common carp on aquatic ecosystems 80 years after "carp as a dominant": ecological insights for fisheries management. *Reviews in Fisheries Science*, **17** (**4**), 524-537.

Weber, M. J., and Brown, M. L. (2011). Relationships among invasive common carp, native fishes and physicochemical characteristics in upper Midwest (USA) lakes. *Ecology of Freshwater Fish*, **20** (**2**), 270-278.

Welcomme, R., Wellby, I., and. Girdler, A., (2010). *Fisheries management: a manual for still-water coarse fisheries*. John Wiley and Sons.

Xia, Y., Li, Y., Zhu, S., Li, J., Li, S., and Li, X. (2020). Individual dietary specialization reduces intraspecific competition, rather than feeding activity, in black amur bream (*Megalobrama terminalis*). *Scientific Reports*, **10** (**1**), 17961.

Yang, Z., Chen, X., Zhao, N., Tang, H., Tao, J., Zhang, P., and Wan, C. (2018). The effect of different habitat types and ontogenetic stages on the diet shift of a critically endangered fish species, *Coreius Guichenoti* (Sauvage and Dabry de Thiersant, 1874). *International Journal of Environmental Research and Public Health*, **15** (**10**), 2240.

Yirga Enawgaw and Solomon Wagaw (2023b). Phytoplankton communities and environmental variables as indicators of ecosystem productivity in a shallow tropical lake. *Journal of Freshwater Ecology*, **38** (**1**), 2216244.

Yirga Enawgaw, Solomon Wagaw, Assefa Wosnie, and Demeke Tegod, (2023). Current fishery status in Ethiopian reservoirs: challenges and management. *Fisheries and Aquatic Sciences*, **26** (**5**), 305-317.

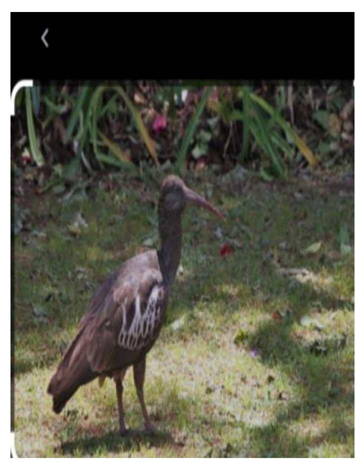
Yirga Enawgaw, Solomon Wagaw, Assefa Wosnie, and Kassahun Tessema, (2023a). Zooplankton as ecosystem indicators and their effects on eutrophication in Lake Arekit (Ethiopia)–implication for freshwater habitat management. *Journal of freshwater ecology*, **38** (**1**), 2287433.

Yirgaw Teferi, Demeke Admassu, and Seyoum Mengistou, (2000). The food and feeding habit of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Chamo, Ethiopia. *SINET: Ethiopian Journal of Science*, **23** (**1**), 1-12.

APPENDICES

Appendix 1: The biodiversity of the study area (Lake Arekit)

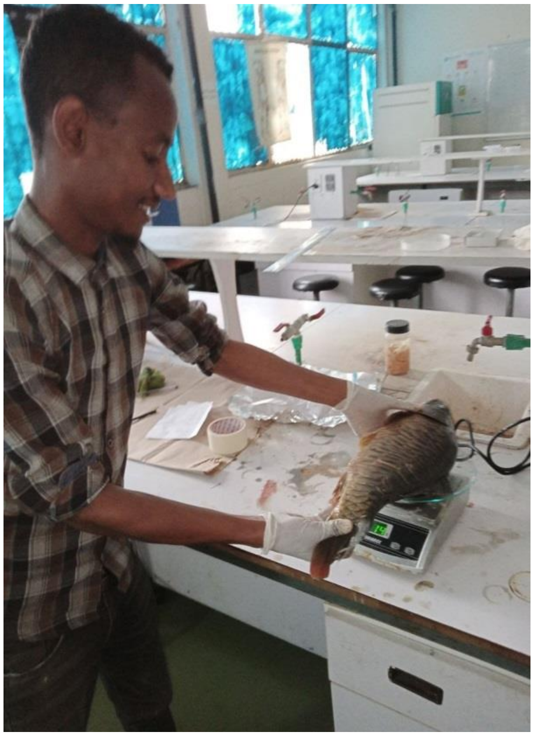
a. Eucalyptus trees around Lake Arekit, Ethiopia (2023)



b. *Cyanochen cyanoptera* **c.** *Columba albitorques* d**.** *Corvus crassirostri* **e.** *Bostrychia carunculata*

Appendix 2: The figure during fish sample collection at Lake Arekit

Appendix 3: Fish length and weight measurement



Appendix 4: The figure during dissection and stomach/gut/ collection

Appendix 5: Gut/Stomach Sample storing

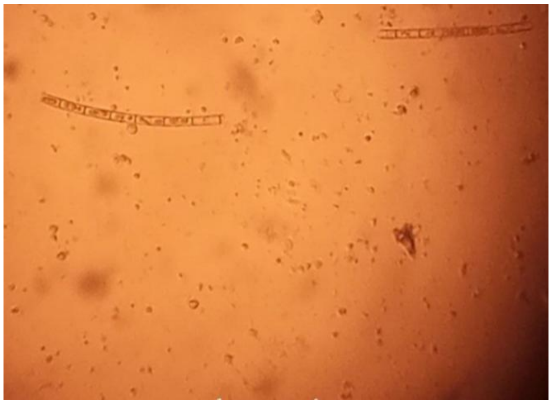
Appendix 6: Microscopic identification of food items

Appendix 7: Some Examples of identified food items

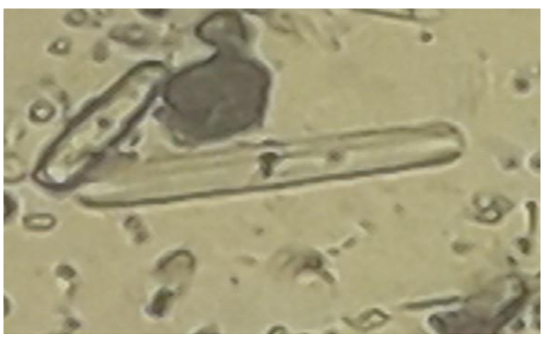
1. Phytoplanktons

<u>i. Diatoms</u>

(**a**=*Melosira sp.*, **b**= *Nitzschia sp.*, **c**=*Pinnularia sp.*, **d**=*Navicula sp*)

a.


b.


c.


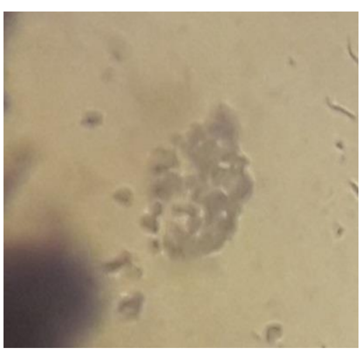
d.

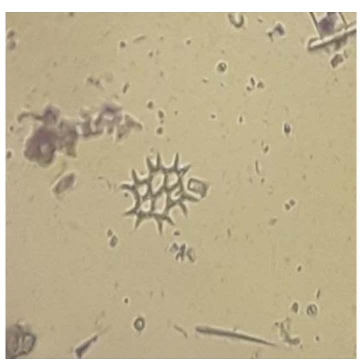

<u>ii. Blue Green Algae</u>

(**a=** *Microcystis sp.*,

<u>iii. Green Algae</u>

(**a=***Pediastrum sp.*, **b=***Ankistrodesmus sp.*)

a.


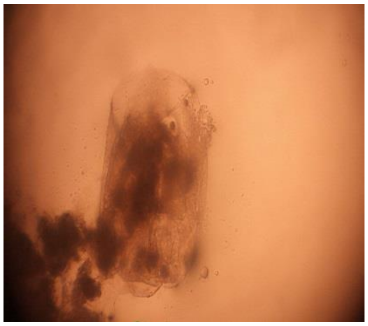
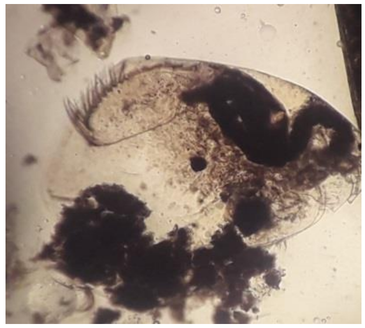
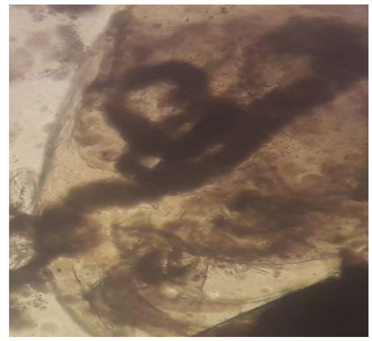
b.


c.


2. Zooplanktons

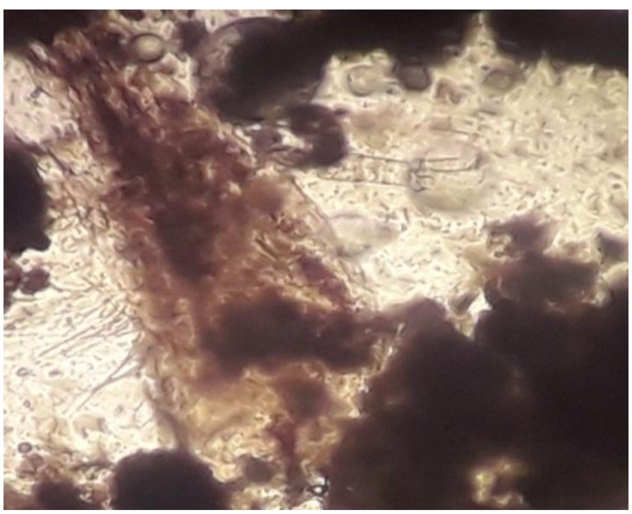
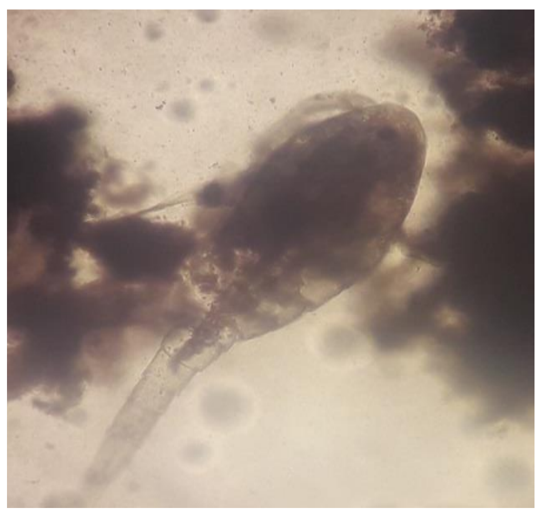
<u>i. Rotifer and Cladocera</u>

(**a=<u>Rotifer</u>** (Bronchionus), **<u>Cladocera</u> (b=***Daphinia sp.,* **c.** *Diaphanoloma sp)*

a.

b.

c.


<u>ii. copepod</u>

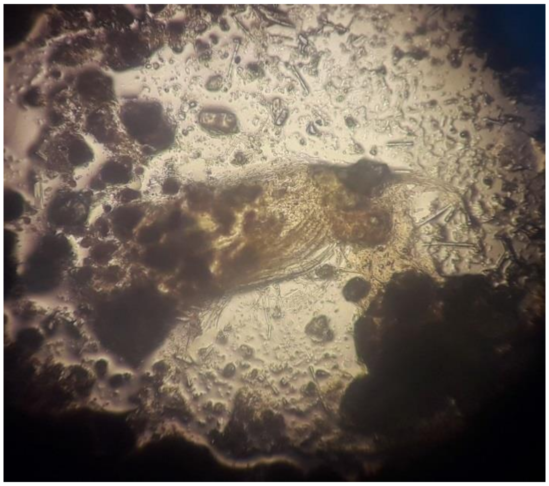
(**a=***Mesocylops sp.* **b=***Thermocylops sp.)*

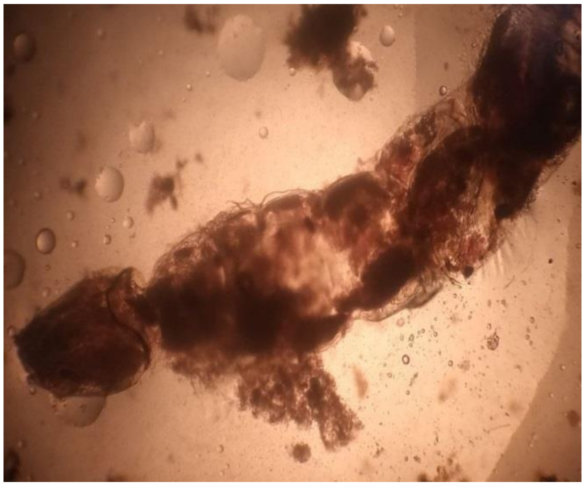
a.

b.


3. Insects

i. Coleoptera

ii. Diptera (*Chironomidae sp.)*

a. 

b. 

4. Aquatic Worms