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COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

SCHOOL OF FISHERIES AND WILDLIFE

DEPARTMENT OF FISHERIES AND AQUATIC SCIENCES

POSTGRADUATE PROGRAM

M.Sc. IN FISHERIES AND AQUACULTURE

FOOD AND FEEDING HABITS OF THE INTRODUCED COMMON CARP *Cyprinus carpio* (LINNAEUS, 1758*)* IN LAKE ARDIBO, SOUTH WOLLO, ETHIOPIA

M.Sc. Thesis

By

Tilahun Ayalew Demsie

July 2024

Bahir Dar, Ethiopia

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SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (M.Sc.) IN "FISHERIES AND AQUACULTURE "

July 2024

Bahir Dar, Ethiopia

Advisor: Degsera Aemro (PhD)

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THESIS APPROVAL SHEET

As the members of the Board of Examiners of the Master of Sciences (M.Sc.) opened thesis defense examination, we have evaluated this thesis studied by **Mr. Tilahun Ayalew Demsie** entitled **"Food and Feeding Habits of the Introduced Common Carp *Cyprinus carpio* (Linnaeus, 1758) in Lake Ardibo, South Wollo, Ethiopia."** We hereby certify that the thesis is accepted for fulfilling the requirements for the degree of Master of Sciences (M.Sc.) in Fisheries and Aquaculture.

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Alamrew Eyayu (PhD)		04/July/2024
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DECLARATION

This is to certify that this thesis titled **Food and Feeding Habits of the Introduced Common Carp *Cyprinus carpio* (Linnaeus, 1758) in Lake Ardibo, South Wollo, Ethiopia"**. Submitted in partial fulfilment of the requirement for the award of the degree of master of science in **"Fisheries and Aquaculture"** to the graduate program of College of Agriculture and Environmental Sciences, Bahir Dar University by **Mr. Tilahun Ayalew Demsie** (ID. No. BDU/1401261) is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for an award of any degree or diploma to the best of our knowledge and belief.

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Signature   Date

Name of Supervisor

Defsera Aemro(PhD)   ______________   03 JUl 2024

(Major A divisor)   Signature   Date

ACKNOWLEDGEMENTS

Above all, thanks to the almighty God who guides and assists me throughout my entire life and provides me meticulousness, serenity, and carefulness for the effective completion of my master's thesis work. Thanks to his mom Saint Virgin Mary for reducing my entire load and duplicating all my strengths throughout my life.

My supreme and sincere gratitude is forwarded to my research supervisor Dr. Degsera Aemro for his unreserved, tangible, critical advice, expert assistance, clarification, ways of doing laboratory experiments as well as procedures, and also for his guidance in writing the research proposal to the end of thesis with careful attention, for his moral support and encouragements, which played the best role and for all-round support to the achievement of this thesis work. I also extend my heartfelt thanks to Mrs. Marshet Teshome and Mrs. Felegush Erarto for their willingness to impart knowledge, demonstrate laboratory procedures, and provide me assistance at the step of laboratory analysis, reading material sharing when I was doing laboratory as well as for their scientific assistance to the effective end of my study. I am truly thankful to the fishery laboratory assistant Mr. Melkamu Agnchew for his facilitating access to the laboratory room and his cooperation was instrumental in ensuring a smooth and efficient workflow during my laboratory analyses. I also extended my thanks to Dr. Alamrew Eyayu and Mr. Amare Dessie for providing essential reading materials. I also extend my thanks to Sirinka Agricultural Researcher, Endalh Makonnen, and Lake Ardibo fishers, particularly Mohamed Ahmed, Jemal Adem, and his son Beker Jemal, for helping me with the field fish sample collection.

My deepest appreciation goes to Assosa University for granting me the opportunity to attend my master's degree and providing me with material, moral, and financial support while I'm studying. I want to sincerely thank Bahir Dar University, College of Agriculture and Environmental Sciences for the provision of different services. I would like to thank the Department of Fisheries and Aquatic Sciences staff for their kind attention throughout my studies.

I would like to gratitude to my mother, father, and siblings for their inspiration, blessings, bearance, and endless love to complete this thesis work. I also express cordial thanks to my friends for their cooperation, cheerfulness, and inspiration during this study. Finally, I would like to thank everyone who supported me directly or indirectly in completing this thesis.

LIST OF ABBREVIATIONS/ACRONYMS

LWR	Length-Weight Relationship
MSY	Maximum Sustainable Yield
SDOI	Schoner Diet Overlap Index
SPSS	Statistical Package for Social Sciences
U test	Mann-Whitney U Test

ABSTRACT

This study was conducted to investigate the food and feeding habits of the introduced common carp, Cyprinus carpio, in Lake Ardibo, Ethiopia during dry (February-March) and wet (July-Augst) months in 2023. Fish specimens were collected by gillnets of various stretched mesh sizes (5cm, 5.8 cm, 6cm, 10cm, 12cm). The gut contents were analyzed using frequency of occurrences and volumetric methods of analysis. A total of 915 fish specimens were collected of which 605(66.12%) guts contained food but 310(33.88%) were empty. The overall sex ratio of female to male C. carpio varied significantly during the sampling period 1:0.72 (p < 0.05). The predominant prey items in terms of frequency of occurrence were zooplankton (72.72%), phytoplankton (66.77%), detritus (66.77%), and macrophyte (39%). Volumetrically, zooplankton (36.27%), phytoplankton (31.41%), macrophyte (15.08%), and detritus (14.81%). However, the contribution of unidentified matters, insects, sand particles, ostracods, gastropods, and fish eggs was low. In the present study, seasonal variation was noted in the diet of C. carpio. Frequency occurrences of phytoplankton and zooplankton varied significantly (X^2 $test, p < 0.05$) *between dry and wet* months. *Likewise, the volumetric contribution of phytoplankton, zooplankton, macrophytes, and detritus varied significantly (U test < 0.05) between dry and wet* months. *Zooplankton, diatom, green algae, macrophyte, and detritus were the major food items during dry* months *occurring at 87.68, 54.77%, 26.6%, 33.6%, and 61.8% of the guts, respectively, and comprising 53.2%, 15.26%, 4.9%, 10.14%, and 12.7% of the entire volume of food items, respectively. Blue-green algae, green algae, detritus, and macrophytes were the dominant food items during wet months, occurring in 59.42%, 61.3%, 76.32%, and 49.3% of the guts, respectively, and comprising 23.1%, 13.1%, 17.98%, and 24.24% of the total volume of prey items, respectively. The frequency occurrence of detritus and macrophyte was comparable during wet and dry* months. *Insects and fish eggs contributed less to the diet during the dry months but were absent in the wet* months. *Schoner Diet Overlap Index revealed there were no significant dietary shifts between juveniles and adults. Both juveniles and adults of C. carpio in Lake Ardibo consumed a variety of prey items. Therefore, based on the result of gut contents; C. carpio is recognized for its omnivorous feeding behavior consuming both plant and animal-based prey. Therefore, C. carpio in Lake Ardibo are deemed suitable candidate fish species for aquaculture development due to their adaptability and versatile dietary habits.*

Keywords/phrases: *C. carpio, diet compositions, feeding habits, food items, Lake Ardibo*

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CHAPTER ONE: INTRODUCTION

1.1. Background and Justification

The fishing industry, which employs 58.5 million people and produces over 214 million fish year-round, is vital to world economies, nutrition, way of life, and food security (FAO, 2022). Fish is the greatest source of protein, which is also regarded as a necessary constituent of a nutritious diet for human consumption, especially in developing nations where a large number of people suffer from malnutrition (Mohanty *et al*., 2019).

The common carp *Cyprinus carpio*, which Linnaeus first identified and described in 1758, nearly 20,000 species were identified (Howes, 1991). The *C. carpio* can adapt to new ecosystems effectively. The species has the potential for rapid expansion and early sexual development. The *C. carpio* predominantly lives in freshwater habitats, which include ponds, lakes, and rivers, and sporadically in brackish habitats (Barus, 2001).

The *C. carpio* became prevalent in areas across the world like Australia, North America, Europe, and Asia (Parkos and Wahl, 2014). The species is cosmopolitan and being investigated as a viable candidate for commercial aquaculture in certain Asian and European nations (Manjappa *et al*., 2011; Rahman, 2015a). The *C. carpio* was originally introduced into African aquatic environments in South Africa's greatest impoundment, Lake Gariep (Henning *et al*., 2008). Also, the species was introduced into Aba Samuel Dam in Ethiopia from Italy in 1940 (Abebe Getahun, 2017). Later the species was introduced in Lake Ziway, in late the 1980s (Lemma Abera *et al*., 2015). Also, the *C. carpio* was introduced in Hashenge, Maybar, and Lake Ardibo (Golubtsov and Darkov, 2008) for the sake of ensuring the accessibility of food in the high land lakes. Adem Mohammed *et al*. (2023) noted that Lake Ardibo is one of Ethiopia's crater highland lakes that benefits the surrounding community by providing a range of ecosystem services like various economic and ecological importances, such as fishing, animal watering, and irrigation to the local community. The lake is one of the important freshwater lakes in northeastern part of Ethiopia and today it supports many fishers and their families, who directly depend on the lake fishery for their protein food source and income generation for sustaining their life.

The C. carpio feeding habit generates significant consequences for the environment (Drenner *et al.*, 1996). The species acts as a nutrient pump by ingesting nutrient-rich benthic sediments including worms, mollusks, zooplankton, worms, aquatic insects as well as insect larvae, and discharging those nutrients again into the column of water in a form that other organisms may consume (Mustafizur *et al*., 2010). However, the *C. carpio* leads to a general decline in water quality, its high fecundity has earned them a reputation as a nuisance (Drenner *et al.*, 1996).

Gut content analysis is a greater source of knowledge on a variety of elements of fish biology and ecology in addition to providing food information (Braga *et al*., 2012). Quantitative evaluation of food and feeding habits are key components of fisheries management and offer valuable insights into feeding patterns when used in the examination of fish stomach contents (Guy and Brown, 2007). The basis for examining trophic relations in the aquatic ecosystems of food is a reliable description of fish diets and feeding habits. Stomach content analysis is also used to assess preferences for food and feeding environments, prey alternatives, the effects of ontogeny, and the development of conservation measures. Studies on fish natural feeding permit a better understanding of the relations among trophic groupings present in aquatic environments, determining the content of consumed food, the framework of food webs, and how they remain stable (Otieno *et al*., 2014; Demeke Admassu *et al*., 2015). Also, the examination of the dietary needs of *C. carpio* allows us to comprehend how the exploitation or introduction of alien species might cause ecosystem disruption. Fish size and weight are a reflection of the quantities of sustenance readily accessible in the aquatic ecosystem, and in every aquatic ecological system, the availability of food influences the fish's condition and its potential to reproduce (Carter *et al*., 2001).

C. carpio is the most economical and ecologically important fish species in Lake Ardibo for the local community. Studies on *C. carpio's* food and feeding habits are of the utmost importance because they establish the groundwork for understanding how trophic relationships work in the research area's aquatic food webs. Besides, the dietary habits of *C. carpio* encompass a number that are crucial ecological elements, which may include habits, habitat utilization, consumption of calories, and interconnections between and among species of *C. carpio* in Lake Ardibo. Even though *C. carpio* has economic importance and it is an aquaculture candidate fish in Ethiopia, little information is available on the food and feeding habits of *C. carpio* in Ethiopian reservoirs and some lakes (Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; Assefa Tessema *et al*., 2020). However, despite its economic and ecological importance to resident communities, there continues to be a paucity of knowledge about the food and consumption habits of *C. carpio* in Lake Ardibo. Therefore, better area-specific information is needed for comprehension of the feeding habits and preferences of *C. carpio* to understand its natural environment, laying a solid basis for understanding trophic interactions of the species with in the lake, as well as promoting fisheries management in Lake Ardibo. As a result of this, this study's is intended to investigate the diet and feeding habits of the introduced *C. carpio* in Lake Ardibo.

1.2. Statement of the Problem

By studying the food and feeding habits of fish, investigators can acquire knowledge about the trophic interaction that occurs in aquatic ecosystems as well as the structure, framework, and sustainability of food webs (Tadesse Fetahi *et al*., 2018; Abebe Tesfaye *et al*., 2020). Likewise, the quantitative analysis of the diet's composition, nutritional value, and seasonal availability serve as the foundations for understanding how the environment influences the condition and growth of fish. As a consequence, understanding the ecological significance and productive capacity of *C. carpio* depends on knowledge of the diet and consumption patterns (Bowen, 1982; Brett, 2002). To boost fisheries productivity and weed control, *C. carpio* was introduced into numerous lakes and reservoirs in Ethiopian lakes including Koka, Ziway, Geray, Hashenge, Hayq, and Ardibo (Golubtsov and Darkov, 2008).

Various authors have studied *C.carpio* in Ethiopian water bodies such as the biology of *C. carpio* (Kassahun Assaminew, 2005; Endalh Mekonnen *et al*., 2019; Agumassie Tesfahun, 2019; Kassahun Tessema *et al*., 2020), stock assessment (Gashaw Tesfaye and Wolff, 2015; Tsegay Teame, 2017), fish health (Alemu Aylate and Alula Alemayehu, 2014; Tigist Zewde *et al*., 2018; Kassahun Tessema *et al*., 2020) were investigated. In addition, previous studies were done on the food and feeding habits of *C. carpio* in Lake Koka by Kassahun Assaminew (2005) and Elias Dedabo *et al.* (2015), in Lake Hayq by Assefa Tessema *et al*. (2020), and in Lake Ziway by Abebe Tesfaye *et al*. (2020). In Lake Ardibo, different findings were made on hydrology (Tenalem Ayenew and Molla Demellie, 2004), bathymetric mapping of the lake (Hassen Yesuf *et al*., 2013), the fish resources potential and some biological aspects (Wubshet Asnake and Minwyelet Mingist, 2018).

C. carpio is a commercially important fish species in Ethiopia (Solomon Wagaw *et al*., 2024). The introduction of *C. carpio* in Lake Ardibo has significantly impacted the aquatic ecosystem, with the species outcompeting other commercially important fish like *Nile tilapia*. The dominance of *C. carpio* has provided vital support to local communities dependent on fisheries for their livelihoods. This key fish species plays a crucial role in the lake's aquatic food web, contributing to the biodiversity and sustainability of the ecosystem while serving as a valuable resource for the surrounding communities. However, despite the importance of *C. carpio* in the lake, to the best of the researcher's knowledge, an investigation into the food and feeding habits of *C. carpio* was not done in Lake Ardibo. Therefore, highlighting a gap in understanding the food and feeding habits of *C. carpio* in Lake Ardibo is important for the successful management of the species and conservation strategies to ensure the sustainability of Lake Ardibo's ecosystem and the well-being of local fishing communities. As well as it is a key factor in sustainable culture in a controlled environment. As a result, there is a need for critical information on the food and feeding habits of *C. carpio*, concerning the relative contribution of each prey item to the diet of *C. carpio,* and ontogenic dietary shifts for appropriate management and utilization of the stock in the lake.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of the current study was to generate baseline information on the food and feeding habits of the introduced *C. carpio* to enable sustainable management of carp fisheries in Lake Ardibo.

1.3.2. Specific objectives

- To identify and determine the kinds of food items and diet composition of *C. carpio* in Lake Ardibo.
- To identify prey organisms in the diet of *C. carpio* in Lake Ardibo
- To compare the relative importance of the different prey items in the diet of *C. carpio* in Lake Ardibo
- To assess the seasonal variations in the diet of *C. carpio* in Lake Ardibo
- To investigate the ontogenic dietary shift in the diet of *C. carpio* in Lake Ardibo

1.4. Research Questions

- What are the main prey items consumed by C. *carpio* in Lake Ardibo?
- Is there any seasonal and ontogenetic dietary variation in *C. carpio*'s feeding habit?

CHAPTER TWO: LITERATURE REVIEW

2.1. Biology and Ecology of *C. carpio*

The *C. carpio* originating in Asia holds a rich historical and cultural significance. It was first domesticated in China during the Tang Dynasty (610-907AD) for culinary and ornamental purposes (Khan *et al*., 2016). Over time, the species has spread across Asia, Europe, and other continents and was primarily introduced by humans for food and recreational fishing activities (Froese and Pauly, 2002). Also, *C. carpio* thrives in various habitats, ranging from pristine lakes to heavily altered water bodies, showcasing its resilience and adaptivity as a species. Due to its enormous popularity, humans extended its distribution to various regions (Balon, 1995).

The body of *C. carpio* becomes extended and slightly compressed, with thick lips shorter barbels on the top lip, and two pairs at the mouth's position (Page and Burr, 1991). The species has a long dorsal fin base with 17-22 branching rays and a robust, front-toothed spine with; an anteriorly concave dorsal fin outline (Pauly and Froese, 2012). The anal fin has six or seven soft rays, and the third dorsal and anal fin spines' posterior edges have pointed spinules. Scales on the lateral line range from 32 to 38 (Page and Burr, 1991). Teeth with flattened crowns make up a fifth of the pharynx. It varies in color from golden yellow ventrally, to brownish-green on the upper sides and the back (Crespi and New, 2009).

C. carpio lives its whole life in streams pools, lakes, and reservoirs. The species prefers larger, warmer, slower-moving bodies of water with soft and muddy bottoms. The species is a tolerant arrange of environmental conditions and a hardy fish that grows in a wide variety of aquatic habitats. The species may endure harsh conditions such as water with little oxygen or water that has a higher temperature change, even temporary freezing. Also, great in many temperate lakes, particularly with shallow eutrophic lakes with substantial littoral zones (Bajer *et al*., 2015). *C. carpio* typically prefers large bodies of water slow-moving or stagnant water (Froese and Pauly, 2002). The species often utilizes river backwaters, deltas, and shallow, vegetated wetlands for spawning and littoral habitat for feeding (Penne and Pierce, 2008).

A comprehensive understanding of fish reproductive biology, as highlighted by Cochrane (2002) and Mathewos Temesgen (2017), plays a crucial role in the sustainable management and optimal utilization of fish stocks. This knowledge is essential for providing sound scientific advice in fishery management practices, ensuring the long-term viability and sustainable production of fish populations (Hossain *et al*., 2016). The ambient water temperature has an enormous effect on the reproductive cycle and the pattern of gonad development in natural habitats. *C. carpio* spawning occurred at a temperature of about 18^0C. *C. carpio* can be capable of spawning throughout the year due to the average monthly water temperature, which ranges from 18.9 to 23.1^0C (Oyugi *et al*., 2011). In a temperate area, female *C. carpio* typically reaches sexual maturity at the age of 4-5 years and spawns between April and July. The species is a seasonal spawner that travels long distances to spawn in shallow waters (ponds, marshes, floodplains, or shallow lakes). *C. carpio* is a highly fertile fish that reaches sexual maturity and grows quickly in its second year of life (Bajer and Sorensen, 2010; Hossain *et al*., 2016).

*C. carpio i*s a polytypic species that can breed year-round in tropical environments and spawn seasonally in temperate waters (Oyugi *et al*., 2011). The species spawned in weed-filled, shallow, marginal environments. *C. carpio* is a species that tends to develop varieties and races in response to selective breeding and external factors. Females are known to lay more than a million eggs in a season (Pauly and Froese, 2012). The species travels to a shallow area of freshwater bodies in the spring to spawn. In the summer, it is spent in places covered in vegetation. Usually, the species migrates to somewhat deeper surroundings and littoral habitats to overwinter. *C. carpio* is frequently migrating long distances to flooded meadows and backwaters that are ideal for spawning. In areas of dense vegetation, females lay their eggs and the eggs stick to aquatic plants. Reproductive success is limited to years with rising water levels that begin in May, as well as years with prolonged periods of high temperatures and prolonged flooding of terrestrial plants in May and June (Kottelat and Freyhof, 2007).

Accurate identification of fish maturity status is a fundamental tool utilized by fisheries biologists and managers for the effective management of exploited fish stocks in the fishery industry (Rahman *et al*., 2018). The size at first sexual maturity of *C. carpio* shows variability across different aquatic water bodies: 17.5 cm for males and 21.5 cm for females *C. carpio* in Lake Hayq (Assefa Tessema *et al*., 2020), 27 cm and 28.3 cm for male and female *C. carpio* in Amerti Reservoir (Mathewos Hailu, 2013), 27 cm and 28.7 cm for male and female *C. carpio* in Lake

Ziway (Lemma Abera *et al*., 2015), and 34 cm and 42 cm male and female *C. carpio* in Lake Naivasha, Kenya (Oyugi, 2012).

Understanding the fecundity of fish species, such as *C. carpio,* is essential for assessing stock potential, life history traits, aquaculture practices, and effective fisheries management, as highlighted by Mathewos Temesgen. (2017). In Lake Hayq, the fecundity range varies from 10,316 to 122,600, with a mean of 28,100 ± 17,462 for *C. carpio* (Assefa Tessema *et al*., 2020). However, Lake Hayq's fecundity values are lower in comparison to other Ethiopian water bodies, such as the Amerti Reservoir where shows a range of 36,955 to 318,584 and a mean of 170,937 ± 1,308 fecundity for *C. carpio* (Mathewos Hailu, 2013), and Lake Ziway with a range of 75,645 to 356,745 and a mean of 210,538 fecundity for *C. carpio* (Lemma Abera *et al*., 2015). The exceptional reproductive potential of *C. carpio* is characterized by early maturation, high fecundity, increased reproductive effort with age, and annual reproduction under favorable conditions for larval survival. The lower absolute fecundity observed in Lake Hayq, in comparison to *C. carpio* in Amerti and Lake Ziway, may be attributed to the smaller size of the fish population in Lake Hayq (Assefa Tessema *et al*., 2020).

C. carpio is well-known and frequently resuspends the sediment at the bottom of bodies of water. It has a significant impact on the watery surroundings due to its activity in browsing for the sediment's benthic macroinvertebrates (Rahman *et al.*, 2008). The species diminishes the clarity of the water by cycling nutrients, clay particles being suspended again in the water, and reducing phytoplankton, zooplankton, and benthic macroinvertebrates. The resuspension of sediment and subsequent transport of nutrients back into the column of water can significantly affect the limnology of ponds. Important key elements that significantly impact sediment resuspension include fish species, size, density, food availability, and foraging behavior (benthic feeding) (Rahman, 2008; Verdegem, *et al*. 2008, 2009). *C. carpio* performs its results in bottom soil resuspension during the digging and sieving of sediments, which boosts the bottom soil's oxygen availability. Diffusion is typically an important way to make oxygen available from the water column into the bottom soil, but this process is quite sluggish and incredibly insufficient, especially in natural feed-driven systems. However, its resuscitation boosts aerobic breakdown in the sediment by increasing oxygen availability in the subsurface soil. In the bottom soil, this mechanism hastens the mineralization of organic materials. Under aerobic conditions as opposed to anaerobic ones, organic matter mineralizes more quickly (Rahman *et al*., 2008).

Benthivorous fish that suspend bottom soil possess an effect on both aquatic ecology as well as fish production. As a result, it is widely practiced in numerous parts of the globe, surrounding Asia and Europe, to boost fish production through the introduction of *C. carpio*. This method can be especially helpful in semi-intensive polyculture systems where fish production is mostly dependent on naturally occurring food sources (Mohapatra *et al*., 2007; Rahman, 2015a). At ideal conditions of density, *C. carpio* possesses a significant synergistic effect on the generation of natural food, which can be eaten by other species of fish residing in the water column. Consequently, the existence of *C. carpio* enhances overall fish production (Rahman, 2015a). Providing favorable conditions at the pond bottom or speeding the migration of dangerous chemicals from the bottom soil upward to the column of water are two more indirect ways that affect aquaculture (Rahman *et al*., 2008).

2.2. Food and Feeding Habits of *C. carpio*

2.2.1. Diet composition of *C. carpio*

Many authors have reported on the diet and feeding habits of *C. carpio* within the natural aquatic environment (Ali *et al.,* 2010; Rahman *et al.,* 2010; Elias Dedabo *et al.*, 2015; Abebe Tesfaye *et al*., 2020 and Assefa Tessema *et al*., 2020). The *C. carpio* prefers to live on the bottom of a body of water. Although the species also looks for food in the middle and upper levels of the water body. Ingesting sediments with their jaws and discharging indigestible particles through opercular holes in their gills. This behavior may cause turbidity to increase and fine particles to be mixed up (Koehn, 2004). The species has a variety of feeding behaviors, although they are all characterized by opportunistic omnivorous feeding behavior (Mustafizur *et al*., 2010). The species consumes a varied choice of food items, such as mollusks, zooplankton, aquatic plants, detritus, phytoplankton, insects, fish parts, and ostracods (Saikia and Das, 2009; Ali *et al*., 2010; Abebe Tesfaye *et al*., 2020).

C. carpio has mechanisms for enhancing its health by altering its food choices, feeding niche, and behavioral patterns (Rahman *et al*., 2010). According to the traditional theory of optimal foraging, the species widens its feeding niche to increase the amount of food it consumes (Rahman and Meyer, 2009). *C. carpio* changes its behavior, feeding niche, and eating behaviors when food is in short supply. The species has an impact on other fish species' feeding and behaviors, which may improve the growth and behavior of other species. The species is exceptionally adaptable when there isn't enough food available. There is proof that it consumes another fish fry in huge quantities when other natural feeds are in short supply (Weber and Brown, 2011).

The juvenile *C. carpio* mostly consumes tiny planktonic species, crustaceans, and insect larvae. Animal-origin foods include fish, shells, aquatic crustaceans, aquatic insects, insect larvae, worms, mollusks, and zooplankton, which are strongly preferred by this species. Larger crustaceans, aquatic insects, and plant materials are all things that *C. carpio* starts eating as they become adult. The species is omnivorous with a high tendency towards the ingesting of benthic organisms and mostly ingests, larvae of insects, mollusks, zooplankton, worms, algae, water insects, detritus, and benthic species (Sivadas and Bhaskaran, 2009; Rahman *et al*., 2010; Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020 and Assefa Tessema *et al*., 2020).

The diet compositions identified and determined in the gut of *C. carpio* in Lake Ziway are macrophyte, detritus, insects, phytoplankton, zooplankton, nematodes, gastropods, ostracods, and unidentified materials (Abebe Tesfaye *et al*., 2020). In Lake Koka, the prey items identified from the gut of *C. carpio* are macrophytes, detritus, insects, phytoplankton, gastropods, and ostracods (Elias Dedabo *et al.*, 2015). Likewise, food organisms identified and determined in the gut of *C. carpio* in Lake Hayq are phytoplankton, zooplankton, insects, macrophyte, detritus, fish scale, fish eggs, and unidentified pre-organisms (Assefa Tessema *et al*., 2020).

2.2.2. Seasonal variation in diet composition of *C. carpio*

The feeding patterns of fish were significantly influenced by seasonal fluctuations and lake characteristics (Flipos Engdaw *et al*., 2013; Solomon Wagaw *et al*., 2022). Seasonal changes are the important features of marine and freshwater environments regulating populations, communities, and finally ecosystem processes by modifying the connectivity to habitat. Some species have been seen to change their food according to the changing seasons because of differences in their relationship to changing ecosystems. Therefore, changes in the amount and availability of food resources can be reflected in variations in diet composition.

Changes in the floodplain's connectivity habitats are the cause of some species changing their diet over the seasons (Murchie *et al*., 2008). Changes in food composition are attributed to intra and interspecific competition considering that the identical resource is shared by several species and that each species can use various resources in succession during the same year (Mérona and Mérona, 2004). The food and feeding habits of *C. carpio* that there are seasonal variations in different water bodies during wet and dry seasons (Rahman *et al.,* 2010; Elias Dedabo *et al.,* 2015; Abebe Tesfaye *et al*., 2020; Assefa Tessema *et al*., 2020). The variety in the types of microorganisms that are consumed may have resulted from advantageous feeding periods, which cause the microbes to shift in certain locations (Ali *et al*., 2010).

The study of *C. carpio's* nutritional variations as a function of the season shows that the nature and importance of the prey ingestion vary as a result of seasons (Dam *et al.,* 2018). The feeding behavior of *C. carpio* varies seasonally (Mustafizur *et al*., 2010). The species predominantly ingest insects during the dry months whereas preferentially consume detritus and macrophytes within the wet months (Elias Dadebo *et al.,* 2015). However, the species consumes the bottom part of the water body during the entire year because of the presence of benthic invertebrates and detritus in *C. carpio* digestive tract (Mustafizur *et al*., 2010).

Seasonal variation of prey items in the diet of *C. carpio* is identified in Lake Hayq, more prey items such as zooplankton, phytoplankton, and insects are ingested in dry seasons. This may be due to higher water temperatures in the tropics (Assefa Tessema *et al*., 2020). Whereas macrophyte and detritus contributions are more during rainy seasons this may be due to runoff and flooding from the catchment (Elias Dadebo *et al*., 2015). The diets of *C. carpio* in Lake Ziway show some seasonal changes (Abebe Tesfaye *et al*., 2020). In terms of frequency of occurrence, detritus is comparable among seasons being relatively higher in June. However, its volumetric contribution is high wet months and low dry months. The highest volume of detritus in wet months may be due to large quantities of plant materials and debris may be carried into the lake by runoff during the wet months and create a larger load of sediments (Elias Dadebo *et al.,* 2015; Abebe Tesfaye *et al*., 2020).

The contribution of macrophytes to the diet of *C. carpio* is comparable among months in Lake Ziway (Abebe Tesfaye *et al*., 2020). The highest and lowest contributions of insects are recorded in May and August, respectively. This may be due to the impact of fine sediment on insects. The contribution of phytoplankton is relatively high in dry months and low in wet months (Abebe Tesfaye *et al*., 2020; Elias Dadebo *et al.,* 2015). The phytoplankton contribution is higher in dry months than in wet months. This may be due to the high flooding from the catchment area may cause fluctuations in water level and increased turbidity of the lake in wet months (Abebe Tesfaye *et al*., 2020). The volumetric contributions and frequency of occurrence of the different prey items of *C. carpio* significantly varied during the dry and wet seasons in Lake Koka (Elias Dadebo *et al.,* 2015). During the dry season, detritus and insects are significant prey organisms to the diet of *C. carpio*. During the wet season, detritus, insects, and macrophytes are the most important food items in the diet of *C. carpio* (Abebe Tesfaye *et al*., 2020).

2.2.3. Ontogenic dietary shift of *C. carpio*

Fish are selective about what they consume since they must have the nutrients they need to live, grow, and reproduce. This suggests that fish have adapted to an unexpected range of environments and challenges, such as the ability to detect meals and the presence of a precise desire to control the intake of certain nutrients (Da *et al*., 2016).

As fishes undergo successive changes in habitat, body form, behavior, and physiological necessity, ontogenetic nutritional alterations occur throughout their entire lifetime (Sánchez-Hernández *et al*., 2019). Ontogenetic changes in food are fairly common in fishes. The reasons for each of these dietary shifts can be due to different factors. Changes in diet are frequently related to habitat changes in many species. It may also be associated with changes in the mouth and oral morphological characteristics. Similar to many other fish, *C. carpio* exhibits ontogenetic changes in feeding preferences (Rahman, 2015b). A lot of species' dietary changes and habitat changes go hand in hand. Alterations in oral morphology and mouth size may also be related to ontogenetic dietary changes. A benthivorous fish, *C. carpio,* primarily eats benthic macroinvertebrates. Although this is an accepted idea, not every *C. carpio* conforms to it. Juvenile fish feed more favorably on zooplankton whereas larger fish avoid it and concentrate on benthic macroinvertebrates (Rahman *et al*., 2009).

Fish have ontogenetic dietary changes because of alterations to their body size and structure (Adeyemi *et al*., 2009). Settlement into the foraging grounds is frequently coupled with the practically ubiquitous occurrence of complicated life cycles that result in significant shifts concerning food and foraging methods (Sivadas and Bhaskaran, 2009). A key aspect of the food of fish is that individuals grow significantly, which is typically correlated with changes in the manner in which their nutritional supplies become utilized. Fish undergo ontogenetic diet shifts throughout their lives, and prey size tends to be associated positively with fish size (Zerihun Desta, 2007).

Fish size and age can affect how they choose their feed. Fish typically eat things that fit in their mouths and that their stomachs can digest (Otieno *et al*., 2014; Wakil *et al.,* 2014*)*. Larva of C. *carpio* has undeveloped digestive tracts and relies on its yolk sacs for 4 to 5 days to provide its initial nutrition. Once they have released their yolk sacs, first larval feeding occurs in the column of water where the fish feed exclusively on zooplankton and occasionally phytoplankton. The size and age variations of the fish's prey might influence their dietary preferences and feeding habits. Fish consume just food that can comfortably fit in their mouths considering the size of their guts. The change in physiology and body structures of an adult fish affects the feeding pattern of *C. carpio*. These modifications can include an enlargement of the alimentary canal and a widening of the mouth gape of the *C. carpio*. When fish get larger, their gut likewise matures and their digestive systems become more sophisticated as well (Otieno *et al*., 2014; Wakil *et al*., 2014). One essential aspect of its feeding is that the individuals grow significantly, which is typically correlated with changes in the way that food resources are used (Zerihun Desta, 2007).

As the fish grow into fry, they retain their predominantly carnivorous feeding habits and can consume larger zooplankton (Cladocerans and copepods). At the fingerling stage, their feeding habit expands as they start to consume feed from the water surface and bottom substrates. They become opportunistic omnivores, expanding their feeding range to include aquatic plants, seeds, insects, and fish larvae (Dam *et al*., 2018). The fish's feeding spectrum expands as they become bigger, including detritus, other mollusks, snails, and small fish. The smaller *C. carpio* mostly consumed animal-derived prey items like insects, zooplankton, and ostracods. Whereas adult *C. carpio* primarily fed on detritus, macrophytes, and phytoplankton (Sivadas and Bhaskaran, 2009). Age-specific changes in the use of habitats are some of the factors for ontogenic dietary changes. The juvenile prefers shallow vegetated areas of the freshwater body and it is fed on benthic invertebrates and mud (Penne and Pierce, 2008).

Diatoms and detritus are the most important food items in the diets of *C. carpio* larvae next to algae and copepods. Juveniles of *C. carpio* mostly consume food items of animal origins like zooplankton, insects, ostracods, gastropods, nematodes, and fish eggs. Also, copepods are the dominant diet for *C. carpio* larvae, next to Daphnia, rotifers, and insects (Ahmed, 2011). Whereas adults more significantly ingest plant matters such as detritus, phytoplankton, and macrophytes in Lake Koka, Lake Ziway, and Hayq. Both immature and mature *C. carpio* ingest both plant and animal-origin food items as studied in Ethiopian lakes by different authors (Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; Assefa Tessema *et al*., 2020).

The nutritional needs of *C. carpio* change based on the fish's age, with juveniles consuming more plankton and adult *C. carpio* taking in more bottom-dwelling food (Rahman *et al.,* 2010). The *C. carpio* having a total length of up to 15.4 cm preferred zooplankton to their diet, in contrast, *C. carpio* avoid zooplankton, with a total length of 18.9 cm (Rahman *et al*., 2009). However, the size of *C. carpio* has a noticeable effect on phytoplankton ingest in the *C. carpio* diet (Rahman, 2015a). Smaller sizes of *C. carpio* in Lake Hayq prefer predominantly phytoplankton and zooplankton species (Assefa Tessema *et al*., 2020). However, adults favor primarily macrophytes and detritus (Assefa Tessema *et al*., 2020). Consistent diet overlap patterns are identified in Lake Hayq, with minimal variations noted across different sampling locations and seasons, indicating a degree of dietary stability in the ecosystem. However, the diets of small-size *C. carpio* are overlapped (Assefa Tessema *et al*., 2020). Food items ingest by *C. carpio* contribute differently to their diet. Adults *C. carpio* ingest a lot of plant-origin prey items, whereas juveniles prefer to eat animal-origin food items.

Smaller *C.carpio* (20 cm TL) consume primarily foods of animal origin in Lake Koka (Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; Assefa Tessema *et al*., 2020). Whereas the *C.carpio* in the size class of 20-29.9 cm TL are ingesting more detritus, macrophytes, and phytoplankton (Elias Dedabo *et al*. 2015). *C.carpio* between 30 and 39.9 cm TL in length predominantly consume phytoplankton, macrophytes, and detritus from the total food items (Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; Assefa Tessema *et al*., 2020). As fish become more mature, they ingest fewer zooplankton, ostracods, and insects (Elias Dedabo *et al*., 2015). When compared with each of the other three size classes, the more substantial class (>40 cm TL) relied less on insects and more on detritus and phytoplankton for food. This may be due to the changes in environmental conditions. Therefore, the result indicates that there are no significant differences between the dietary habits among *C. carpio* in the different size classes in Lake Koka (Elias Dedabo *et al*., 2015).

A high similarity food items consumed by juvenile and adult *C. carpio* in Lake Ziway (Abebe Tesfaye *et al*., 2020). Juvenile fish preferentially consume animal-origin food items including zooplankton and insects. Whereas adults predominantly ingest detritus and macrophytes or more plant-origin food items. Therefore, the result indicates the absence of considerable nutritional overlap between adults and juvenile *C. carpio* (Abebe Tesfaye *et al*., 2020). The ontogenetic dietary changes in fish may be caused by a variety of situations. Some of these characteristics comprise the digestive system's varying stages of growth as well as shifts in habitat utilization which are particular to different stages (Sivadas and Bhaskaran, 2009).

2.3. The Relative Importance of Food Items in the Diet of *C. carpio*

2.3.1. Types of major food items in the diet of *C. carpio*

The major relative importance of food items identified and determined in *C. carpio* diet across various Ethiopian lakes include zooplankton, insects, and detritus in Lake Ziway (Abebe Tesfaye *et al*., 2020); detritus, insects, and macrophytes in Lake Koka (Elias Dadebo *et al*., 2015); and diatoms, Cladocera, macrophytes, and detritus in Lake Hayq (Assefa Tessema *et al*., 2020). Moreover, detritus and insects emerge as significant prey organisms determined in the *C. carpio* diet in both Lake Ziway and Lake Koka (Elias Dadebo *et al*., 2015; Abebe Tesfaye *et al*., 2020). The prevalence of macrophytes and detritus as dominant prey items further underscores their importance in the diet of *C. carpio* across several Ethiopian lakes (Elias Dadebo *et al*., 2015; Abebe Tesfaye *et al*., 2020; Assefa Tessema *et al.*, 2020).

2.3.2. Nutritional composition and value of different food items in the diet of *C. carpio*

Typically, *C. carpio* needs to eat around 12g of protein for every kg of their body weight, which equates to 30-35% protein in the diet. They perform well with dietary fat levels of between 5-15%. Also, the species required is 30-40% carbohydrate; this is considerably higher than in carnivorous species' diets because *C. carpio* has longer intestines and can digest carbohydrates more readily.

Vitamin requirements cannot be determined as easily as the main food groups because there are lots of depending factors, such as age and water temperature. Furthermore, some vitamins can be synthesized within the *C. carpio's* gut - such as vitamin C - which means they don't have to be included in their diet. Minerals are typically included within the diet, but the fish will also uptake certain minerals directly from the water via the gills. Natural food organisms can satisfy all the protein, lipid, and energy requirements of *C. carpio*. Their average composition is 85.5% water, 7.4% protein (52.1% of dry matter), 3.8% carbohydrate (27.3% of dry matter), 1.1% lipid (7.7% of dry matter), 1.1% ash (7.7% of dry matter) (Albrecht and Breitsprecher, 1969).

It is only at the advanced fry stage that the digestive tract is entirely developed. By this time, the qualitative development of both the mouth and the digestive tract is completed (Lavens and Sorgeloos, 1996). During the early development of the digestive tract of *C. carpio*, the larvae do not have the needed set of enzymes to digest the ingested food. After the filling of the swim bladder and the intensification of exogenous feeding, the trypsin activity rises. Later (within about 15 days), chymotrypsin activity appears and amino peptidase activity then increases (Lavens and Sorgeloos, 1996). The mouth of the *C. carpio* is relatively large and opens in an accordion-like fashion, enabling the fish to dig in the mud of the bottom. There are two pairs of barbels, one pair on the upper lip and the other pair at the corners of the lower lip. They function as feelers for searching for food. There are 5-5 molar-like pharyngeal teeth that serve to grind the consumed food and feed (Froese and Pauly, 2012).

The *C. carpio* has no stomach; therefore, the ingested food arriving from the mouth passes directly into the intestine. The overall intestinal length relative to the total body length is related to the feeding habits of the fish species under consideration. In the case of omnivorous fish species such as *C. carpio*, the actual length of the intestine depends on, among others, the food and feeds consumed during the early stages of life (Hepher, 1988).

CHAPTER THREE: MATERIALS AND METHODS

3.1. Description of Study Area

The study was conducted in Lake Ardibo, which is found in the South Wollo administrative zone, Amhara National Regional State, northeastern part of Ethiopia. It is located at 11º10′ 26.9″ N, 39º 45′ 19.2″ E an altitude of 2000 m a.s.l (Figure 3.1). The lake area is roughly 21 km^2 (Wubshet Asnake and Minwyelet Mingist, 2018). The region is generally high altitude as evidenced by the distribution of bushes and trees along with natural grazing fields. The lake is mostly utilized for irrigation, fishing, and other societal necessities. More encroaching papyrus marshes around the lake provide a special habitat for the biodiversity of freshwater and a supply of animal feed throughout the dry season. The yearly average temperature and precipitation are 18°C and 1158 mm, respectively, in the lake area (Wubshet Asnake and Minwyelet Mingist, 2018).

The maximum depth of the lake is 65 meters. The pH of the lake is approximately 8.5. The surface oxygen concentration is around 4.15 mg/L (Wubshet Asnake and Minwyelet Mingist, 2018). It is among one of the most significant bird locations in Ethiopia due to different bird species that have been identified in and surrounding the lake. The fish species in the lake are not native to the area. Nile tilapia (*Oreochromis niloticus*) and *C. carpio*, were two fish species introduced to the lake for fishing (South Wollo Zone Livestock and Fisheries Development Office reports, 2009). The lake delivered a maximum sustainable yield (MSY) estimated at 206 tons of fish production annually (Wubshet Asnake and Minwyelet Mingist, 2018).

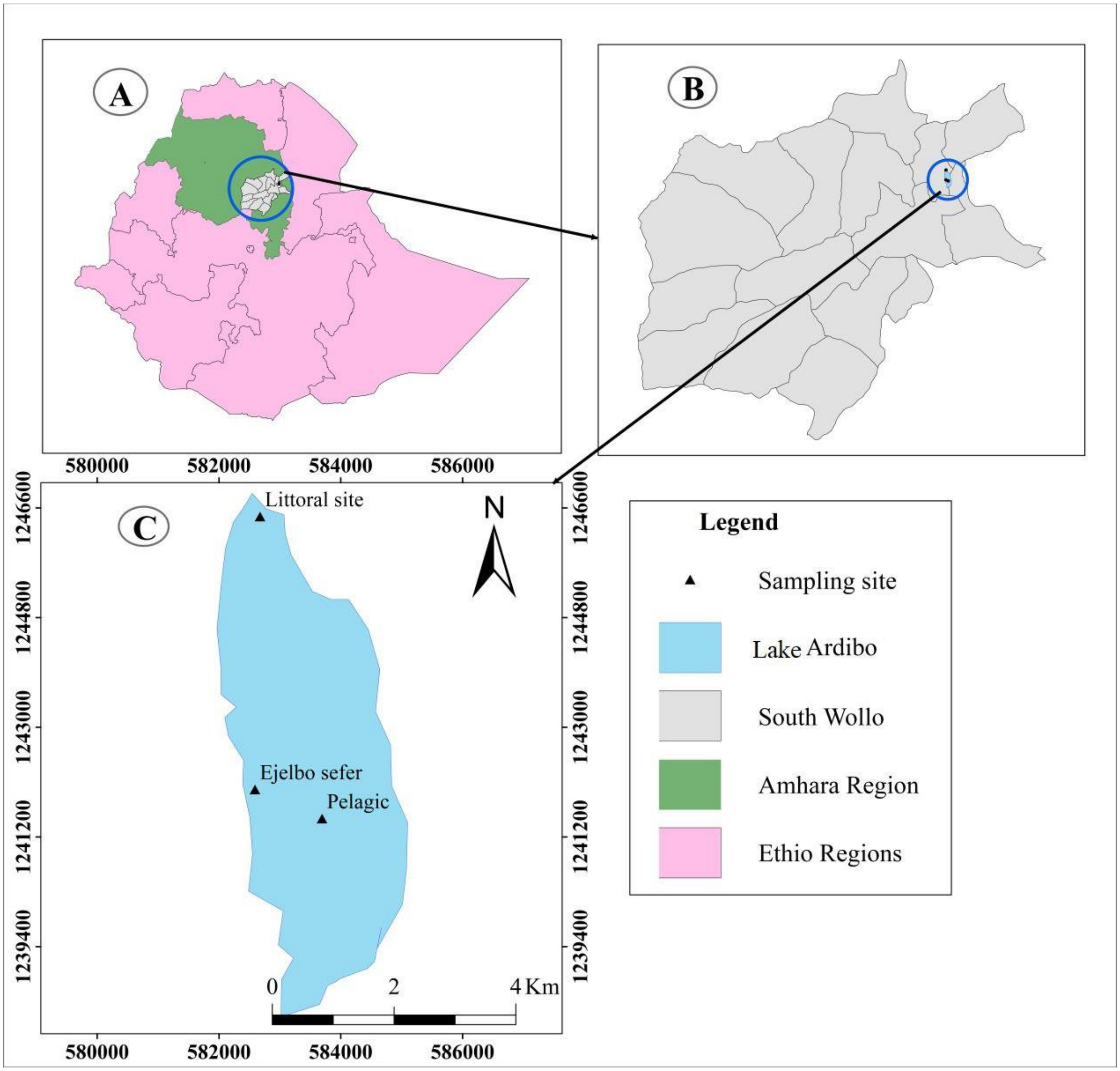

Figure 3.1: Map of the study area and sampling sites

3.2. Fish Sampling and Measurements

The specific locations for the sampling site were established using GPS, and a geographical map was generated. Three specific sampling sites S1 (Menafesha), S2 (pelagic), and S3 (Ejelbo Sefer) were selected purposively based on water depth, accessibility, fish availability, suitable for the gillnet setting, and the impact of activities that involve humans and animals. During, the sampling period, a total of 915 *C. carpio* specimens were collected in 2023 during dry months (February-

March) and wet months (July - August) using monofilament and multifilament gillnets of different mesh sizes (stretched mesh sizes of 5 cm, 5.8 cm, 6 cm, 8 cm, 10 cm, 12 cm) from selected sampling sites for gut content analysis. Mono and multifilament gillnets were set at 6:00 pm and withdrawn the subsequent morning at 1:00 am local time. Also, the gillnets net was set in the afternoon (about 05:00 pm) and lifted in the following morning (about 07:00 am).

After the collection of fish samples, total lengths (TL), fork length (FL), and standard length (SL) were measured as soon as captured, to the nearest centimeter, using a measuring board. Using a digital balance, the total weight (TW) was measured to the nearest 0.1 gram. The digestive tracts of each specimen were then opened using dissecting kits, and the gut contents were examined to see if any food was present.

All non-empty specimens were collected in plastic sampling bottles, labeled, and preserved in a 5% formaldehyde solution for further gut content analysis. Following that, the gut samples were transported to the Fisheries Laboratory, Department of Fisheries and Aquatic Sciences, College of Agriculture and Environmental Sciences, Bahir Dar University for further laboratory analysis. Both qualitative and quantitative methods of fish gut contents analysis were applied to measure the collected gut contents. With the use of reliable literature sources and a wealth of knowledge, qualitative analysis was applied to determine the prey items in *C. carpio's* gut content.

3.3. Sex Ratio

The sex ratio was determined by using the following formula (Vazzoler, 1997).

$$Sex\ ratio = \frac{Number\ of\ females}{Number\ of\ males}$$

3.4. Food and Feeding Habits

After the gut contents were carefully extracted and transferred to a Petri dish for microscopic analysis. To ensure accurate identification, the samples were diluted with water and examined using both dissecting and compound microscopes Gilbert (1980), following the protocol. Visual recognition was used to identify larger food items, while smaller food items were scrutinized using dissecting and compound microscopes (LEICA 54E, 10X/23, and OPTIKA E- PLAN, 10X/0.25) for precise identification. The food item that was observed, identified, and classified towards the taxonomic level that is to the lowest possible taxa using an identification key in the literature (Zealand, 2000; Gerber and Gabriel, 2002; Green *et al.*, 2004; Witty, 2004; Taylor *et al.*, 2007).

3.5. Relative Importance of Food Items

3.5.1. Frequency of occurrence (%F)

The percentage of all non-empty *C. carpio* guts that contained a specific food item in the fish gut samples was examined. Through this method, the percentage of the population that consumes a specific food item can be estimated (Hyslop, 1980).

$$\%\ \text{Frequency of Occurrence} = \frac{\text{Total number of guts with a particular prey item}}{\text{Total number of guts with food}} * 100$$

3.5.2. Volumetric analysis (%V)

Each gut content sample extracted from the fish species was meticulously diluted with a precisely measured drop of water within a graduated cylinder. Subsequently, a single droplet of the diluted sample was carefully dispensed onto Petri dishes using a pipette, and then, identified and classified into distinct taxonomic categories. The volumetric percentage of each prey organism was, then, accurately estimated by eye estimation relative to the entirety of food items present in the droplet, taking into account their size and abundance. Specifically, a minimum of three meticulous observations were conducted on a single droplet of diluted sample extracted from each specimen. This rigorous approach ensures the robustness of the estimations regarding the volumetric percentage of individual prey items. By subjecting each sample to multiple examinations, any potential variability or inconsistency in prey composition is accurately accounted for; thus, enhancing the accuracy and reliability. To sum up, visual estimation was employed to estimate the volume of each prey item relative to the entirety of prey organisms identified. The volumetric percentage of each prey item within every individual specimen of *C. carpio* was calculated employing the formula developed by Bowen (1983).

$$\%\ \text{of Volume} = \frac{\text{The volume of one prey item found in all sampled specimen}}{\text{The Volume of all prey items in all sampled specimens}} * 100$$

3.6. Seasonal Variation

The frequency of occurrence and volumetric contribution of the diets consumed over the two seasons were compared. Foods that were the most frequently encountered and contributed the most were considered to be the most significant foods for the fish during the specified seasons. Whereas, foods that made little contributions have been classified as substantially lesser in significance.

3.7. Ontogenetic Dietary Shifts

First, the importance of different prey organisms in the different size classes of *C. carpio* was determined by dividing the total length of the fish into three size classes (I: ≤ 10 cm TL, II: 10-22 cm TL, III: 22-35 cm TL) (Abebe Tesfaye *et al*., 2020). In the present study, the size differentiation between juvenile and adult stages of *C. carpio* was based on gonadal development. Fish measuring 10 cm TL or less exhibited thread-like, flesh-colored gonads, indicative of immaturity. Also, the corresponding items of food contributions were sorted in Microsoft Excel and organized into an ascending sequence after every food item was determined and volumetrically summed. For a particular size class, the foods that contribute most volumetrically to the diet of *C. carpio* have been considered the dominant food item. Ontogenetic dietary changes were used to categorize the fish specimens., and the % mean volume of various foods was calculated (Wallace, 1981; Schoener, 1970).

$$\alpha = 1 - 0.5\left(\sum_{i=1}^{n} |\mathrm{Pxi} - \mathrm{Pyi}|\right)$$

Where, "α" is the percentage overlap of the Schoner Diet Overlap Index between size class "x" and "y". "Pxi" and "Pyi" are the proportion 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 unless there is no dietary shift between the size class of *C. carpio* (Mathur, 1977).

3.8. Statistical Analysis

The frequency of occurrences of the various food groups during the dry and wet seasons was compared using SPSS version 27 software. A non-parametric Mann-Whitney U-test was used, to compare the volumetric contribution of food items in the two seasons because the data did not meet the required normality assumptions. Additionally, using the Schoener Diet Overlap Index (SDOI), the dietary overlap between fish of various size classes was determined (Schoener, 1970; Wallace, 1981).

CHAPTER FOUR: RESULTS

4.1. Sex Ratio

From the 915 fish specimens collected, 383 (41.85%) were females and 532 (58.15%) were males, indicating an important variation during the sampling period and the ratio of males and females was 1:0.72. Males were more numerous than females (X^2 test, $p < 0.05$).

4.2. Diet composition in *C. carpio*

The *C. carpio* specimens containing prey organisms varied in length from 7 to 35 cm. Out of the total number of specimens collected, 605 (66.12%) had different foods in their stomach, while the remaining 310 (33.88%) had empty stomachs. Prey items like macrophytes, gastropods, ostracods, fish eggs, sand particles, detritus, phytoplankton, zooplankton, insects, and unidentified matter were identified in the diet of *C. carpio*.

4.3. Relative Contribution of Food Items in the Diet of *C. carpio*

C. carpio in Lake Ardibo fed on a variety of prey organisms, such as macrophyte, phytoplankton, zooplankton, insects, fish eggs, gastropoda, ostracode, sand particles, detritus, and unidentified matter. Among these foods, most of the food items consumed were phytoplankton, detritus, zooplankton, and macrophytes. The remaining other prey items contributed least to the *C. carpio's* diet both in terms of frequency of occurrence and volumetric contribution.

Zooplankton (Cladoceran, copepod, rotifers) were the most substantial food item in the diet of *C. carpio*. Zooplankton was found in 72.72% of the stomachs and made up 36.27% of the entire volume of prey items ingested. Cladocera was the most prevalent prey organism among the zooplankton taxa, appearing 66.77% of the time and accounting for 27.37% of the total volume of food items. Copepods were the second most significant food item, occurring in 57.19% of stomachs and accounting for 8.2% of the prey volume. Whereas rotifers were the least important food item in the diet, contributing 0.64% and 9.42%, in terms of volumetric contribution and frequency of occurrence, respectively.

Phytoplankton was the second most important food item next to zooplankton in *C. carpio's* diet. Among the phytoplankton groups, green algae, blue-green algae, diatom, euglenoids, and dinoflagellates were identified with a frequency of occurrences of 38.51%, 24.79%, 50, 1.48%, and 8.92%, respectively. Likewise, volumetrically contributed 8.22%, 9.67%, 12.41%, 0.1 and 0.82% to the *C. carpio's* diet respectively. In addition, from the identified euglenoid, *phacus* sp. was observed in 1.48% of the stomach and volumetrically contributed 0.1%. Whereas, from dinoflagellates, *peridininum* sp. occurred in 8.92% of the guts and 0.82% of the volumetric contribution.

Macrophytes and detritus were the most predominant important food items, respectively next to zooplankton and phytoplankton, occurring in 39% and 15.08% of the stomach and contributing to 66.77% and 14.81% of the entire volume of the food items, respectively. In comparison to the other food items, the rate at which insects happen and the volumetric contribution of insects were low and nearly insignificant, it occurred in 6.11% of stomachs and 1.23% of the entire volume of food items, in the *C. carpio* diet respectively. From the insect taxa, Diptera, Plecoptera, Ephemeroptera, Coleoptera, and Hemiptera occurred a frequency occurrence of 4.95%, 1.98%, 4.13%, 2.8%, 1.65 constituted food items of the *C. carpio's* diet. Likewise, volumetrically 0.36%, 0.12%, 0.41%, 0.2%, and 0.11% constituted the diet of *C. carpio*, respectively. Other food items identified in *C. carpio's* diet were fish eggs, gastropods, ostracode, sand particles, and unidentified matter which occurred in 0.33%, 0.99%, 1.32%, 1.98%, and 4.62% in the *C. carpio's* gut, respectively, and volumetrically accounted for 0.01%, 0.06%, 0.09%, 0.21%, and 0.22% of the entire volume of food items, respectively.

Table 4.1: Frequency of occurrence and volumetric contribution of different food items in the diet of *C. carpio* sampled from Lake Ardibo (n = 605)

Food items	**Frequency of occurrence**		**Volumetric contribution**	
	Number	**Percentage**	**Volume (ml)**	**Percentage**
Macrophytes	**236**	**39**	**598.3**	**15.08**
Phytoplankton	**404**	**66.77**	**1245.42**	**31.41**
Green algae	233	38.51	326.1	8.22
Scenedesmus sp.	163	26.94	117	2.95
Spirogyra sp.	18	2.98	8.73	0.22
Chlamydomonas sp.	51	8.42	20.47	0.51
Pediastrum sp.	12	1.98	7.57	0.19
Clostrium sp.	17	2.8	9.1	0.23
Coelastrium sp.	25	4.13	15.76	0.39
Cosmarium sp.	81	13.38	63.58	1.6
Micrasterias sp.	15	2.48	8.33	0.21
Oocyts sp.	46	7.6	44.23	1.11
Tetraedron sp.	13	2.14	10.35	0.26
Volvox sp.	12	1.98	4.59	0.11
Chlorella sp.	18	2.97	9.2	0.23
Dictyosphaerium sp.	8	1.32	3.44	0.08
Blue-green algae	150	24.79	383.4	9.67
Osillatoria sp.	25	4.13	16.18	0.4
Microsytis sp.	136	22.48	321.93	8.11
Mersimopedia sp.	24	3.96	17.41	0.44
Anabaena sp.	28	4.62	27.62	0.69
Diatom	303	50	492.1	12.41
Aulacoseria sp.	119	19.6	54.95	1.38
Gomphonema sp.	122	20.16	34.96	0.88
Cymbella sp.	209	34.54	101.08	2.55
Epithemia sp.	32	5.29	13.41	0.33
Eunotia sp.	78	12.89	26.4	0.66
Diatoma sp.	27	4.46	10.49	0.26
Coccocneis sp.	30	4.95	8.24	0.21
Amphora sp.	71	11.73	24.53	0.61
Craticula sp.	20	3.3	8.43	0.21
Rhopalodia sp.	6	1	1.95	0.05
Pinnularia sp.	18	2.97	5.64	0.14
Peronia sp.	82	13.55	40.35	1.02
Cymatopleura sp.	10	1.65	4.22	0.11
Melosira sp.	22	3.63	6.29	0.15
Navicula sp.	141	23.3	68.15	1.71

Surirella sp.	10	1.65	5.04	0.13
Gyrosigma sp.	10	1.65	3.63	0.09
Flagilaria sp.	14	2.31	5.26	0.13
Thalasiosira sp.	59	9.75	26.8	0.67
Stauroneis sp.	10	1.65	2.48	0.06
Thelassionema sp.	8	1.32	2.65	0.06
Nitschia sp.	90	14.87	28.7	0.72
Egulenoid	9	1.48	4.2	0.1
Phacus sp.	9	1.48	4.2	0.1
Dinoflaglaates	54	8.92	32.7	0.82
Peridininum sp.	54	8.92	32.7	0.82
Zooplankton	**440**	**72.72**	**1438.2**	**36.27**
Cladocera	404	66.77	1085.3	27.37
Copepode	346	57.19	325.35	8.2
Rotifer	57	9.42	25.6	0.64
Insects	**37**	**6.11**	**49.53**	**1.23**
Diptera	30	4.95	14.56	0.36
Chironomid larvae	30	4.95	14.56	0.36
Plecopetra	12	1.98	5.03	0.12
Ephmeropetra	25	4.13	16.37	0.41
Coleopetra	17	2.8	8.26	0.2
Hemipetra	10	1.65	4.38	0.11
Fish egg	**2**	**0.33**	**0.41**	**0.01**
Gastropoda	**6**	**0.99**	**2.44**	**0.06**
Ostracode	**8**	**1.32**	**3.57**	**0.09**
Sand particles	**12**	**1.98**	**8.5**	**0.21**
Detritus	**404**	**66.77**	**587.31**	**14.81**
Unidentified matter	**28**	**4.62**	**8.66**	**0.22**

N.B. The volume of major food items in bolds adds up 100% in volumetric analysis.

4.4. Seasonal Variation in the Diet of *C. carpio*

Food items ingested by *C. carpio* from Lake Ardibo revealed seasonal variations in both seasons. Both in the dry (February-March) and wet (July-Augst) months the frequency occurrence of phytoplankton and zooplankton in the diet *C. carpio* varied significantly (X^2 test, p < 0.05). Likewise, the volumetric contribution of phytoplankton, zooplankton, macrophyte, detritus and showed notable differences between dry and wet months (U test, p <0.05). Conversely, both in terms of the volumetric contribution and frequency of occurrence of unidentified matter, ostracod, and gastropod confirmed that no apparent change was between wet and dry months. All food items were ingested by *C. carpio* in both months, except fish eggs, sand particles, and insects. However, the proportion of different prey items was different both in wet and dry months.

In the *C. carpio* diet, the volumetric contribution and frequency of occurrence of zooplankton varied significantly between months. It is the most significant food source during the dry months, occurring in 87.68% of the gut and making up 53.2% of the entire volume of prey items. However, during the wet months, its frequency contribution dropped to 43.96% of the stomachs and made up 10.81% of the overall volume of food items. Of the zooplankton taxa that were observed, Cladocera was the most significant, accounting for 81.15% of the stomachs and 40.7% of the overall volume during the dry months. Conversely, during the wet months, the proportion of Cladocera decreased, appearing in 39.13% of the stomachs and making up 7.3% of the entire volume of food content (Table 4.2, Figure 4.1).

Copepods were found in 72.1% of the stomachs, and they made up 11.34% of the entire volume of food during the dry months. In contrast to this, during the wet months, its percentage decreased to 28.5% of the stomachs examined which contributed to 3.48% of the entire volume of food. When comparing the frequency percentage and total volume of prey items in the *C. carpio'*s diet, rotifer was comparatively less important than Cladocera and copepod. The frequency of occurrence and volumetric contribution of rotifer was 14.32% and 1.07%, respectively during the dry months. Contrary to this, during wet months rotifer was nonexistent (Table 4.2, Figure 4.1).

The volumetric contribution and frequency occurrence of phytoplankton in *C. carpio's* diet varied significantly in dry and wet months. Even though, phytoplankton constituted the most popular food source for the *C. carpio* diet in both seasons. Its contribution was greater during the wet months, occurring 84.5% of the time and making up 46.1% of the entire volume. It had a frequency occurrence of 57.5% of the stomachs and made up 21.5% of the entire volume of diet during the dry months (Table 4.2, Figure 4.1).

Among the phytoplankton groups, diatoms were the most significant prey items; they were found in 54.77% of stomachs which made up 15.26% of the entire volume of prey items during dry months. However, during wet months, its share of the diet decreased to 41.06% of the stomach and it contained 8.13% of the total volume of food. During dry months green algae were the second most important food source among the identified phytoplankton groups next to diatoms, they comprise a frequency occurrence of 26.6% and 4.9% of the entire food volume, respectively. Also, the contribution of green algae was comparatively higher in the wet months. It contributed a frequency of 61.3% and 13.1%, to the entire volume of food items (Table 4.2, Figure 4.1).

During the dry season, the frequency occurrence of Oocyts (1.5%), and Cosmarium (8.8%) were slightly lower than in wet months. The volumetric contribution of Cosmarium (1.09%) during the dry months was lower as compared to its (2.36%) volumetric contribution during the wet months. Whereas, during the wet months, the frequency occurrence of microcysts (58.94%),) was relatively higher than its frequency occurrence (3.51%) during the dry months Likewise, the volumetric contribution of microcysts (0.36%) during the dry months was lower as compared to its volumetric contribution (19.78%) during the wet months (Table 4.2, Figure 4.1).

In terms of volumetric contribution, detritus revealed a seasonal variation in *C. carpio*'s diet composition. Despite this, in terms of the frequency of occurrences, it has not varied significantly. Which was comparable during the dry and wet months being relatively higher in wet months. It is the other most relevant prey item to the diet both in dry and wet months. During the dry months, detritus was found in 61.8% of the gut contents and made up 12.7% of the entire food volume. However, its contribution was relatively higher during the wet season; it occurred in 76.32% of the stomachs, making up 17.98% of the total volume of prey items (Table 4.2, Figure 4.1).

The importance and contribution of gastropods and ostracode were smaller during both the dry and wet months, ostracode occurred in 1.5% and 0.1% of the stomachs and accounted for 0.1% and 0.05% of the total volume, respectively. Similarly, the gastropods occurred in 0.96% and

0.08% of the stomachs and comprised 1% and 0.04% of the total volume of prey organisms during dry and wet months, respectively (Table 4.2, Figure 4.1).

Macrophytes' volumetric contribution varied significantly between dry and wet months. However, their frequency of occurrence did not vary significantly. It was comparable in both months being relatively high in wet months. It is the other most significant source of food for *C. carpio* both during the dry and wet months. During wet months, macrophytes occurred in 49.3% and, it contributed to 24.24% of the total volume of food. During dry months, it occurred at a frequency of 33.6% and 10.14% of the entire volume of food (Table 4.2, Figure 4.1). The sand particles were very low to the *C. carpio's* diet, and its contribution occurred a frequency occurrence of 5.79% and 0.53% of the total volume of food items in the wet months. On the other hand, sand particles were absent in the dry months. In the *C. carpio* diet, unidentified matter did not vary significantly during dry and wet months both in terms of volumetric contribution and frequency of occurrence and its contribution was quite low (Table 4.2, Figures 4.1).

Table 4.2: Relative contribution of different food items in the diet of *C. carpio* during dry (n= 398) and wet months (n=207)

	Frequency of occurrence (%)		Volumetric contribution (%)	
Food items	**Dry months**	**Wet months**	**Dry months**	**Wet months**
Macrophytes	**33.6**	**49.3**	**10.14**	**24.24**
Phytoplankton	**57.5**	**84.5**	**21.5**	**46.1**
Green algae	26.6	61.3	4.9	13.1
Scenedesmus sp.	13.8	52.1	1.3	5.4
Spirogyra sp.	2.2	4.3	0.2	0.3
Chlamydomonas sp.	10.05	5.3	0.59	0.4
Pediastrum sp.	2.26	1.45	0.22	0.14
Clostrium sp.	2.4	3.01	0.24	0.2
Coelastrum sp.	5.52	1.44	0.56	0.14
Cosmarium sp.	8.8	23.67	1.09	2.36
Micrastriasis sp.	1.5	4.34	0.08	0.39
Oocyts sp.	1.5	19.32	0.09	2.65
Tetrastrum sp.	1	4.34	0.05	0.56
Volvox sp.	1.75	2.41	0.05	0.2
Chlorella sp.	3.52	1.93	0.22	0.23
Dictyosphaerium sp.	1.5	0.96	0.14	0.12
Blue-green algae	6.78	59.42	0.73	23.1
Osillatoria sp.	2.01	8.21	0.15	0.79
Microsytis sp.	3.51	58.94	0.36	19.78
Mersimopedia sp.	1.5	8.69	0.09	0.95
Anabaena sp.	1.75	10.14	0.08	1.61
Diatom	54.77	41.06	15.26	8.13
Aulacoseira sp.	18.59	21.73	0.98	2
Gomphonema sp.	25.62	9.66	1.23	0.35
Cymbella sp.	40.2	23.67	3.2	1.58
Epithomia sp.	6.28	3.38	0.38	0.26
Eunotia sp.	15.82	7.24	0.88	0.33
Diatoma sp.	5.53	2.41	0.34	0.12
Coccocneis sp.	4.77	5.31	0.25	0.14
Amphora sp.	12.81	9.66	0.63	0.6
Craticula sp.	3.52	2.89	0.21	0.22
Rhopalodia sp.	1.5	-	0.08	-
Pinnularia sp.	3.01	2.89	0.16	0.11
Peronia sp.	19.34	2.41	1.61	0.11
Cymatopleura sp.	1.5	1.93	0.08	0.14
Melosira sp.	4.52	1.93	0.16	0.15
Navicula sp.	28.64	13.04	2.31	0.82

Surirella sp.	2.01	0.96	0.13	0.12
Gyrosigma sp.	2.51	-	0.15	-
Fragilaria sp.	2.01	2.9	0.11	0.16
Thalasiosira sp.	10.8	7.72	0.84	0.43
Stauroneis sp.	1.5	1.93	0.07	0.05
Thelassionema sp.	1	1.93	0.05	0.08
Nitzschia sp.	19.3	6.28	1	0.31
Egulenoid	1.25	1.93	0.07	0.15
Phacus sp.	1.25	1.93	0.07	0.15
Dinoflagellates	2.51	21.25	0.29	1.62
Peridininum sp.	2.51	21.25	0.29	1.62
Zooplankton	**87.68**	**43.96**	**53.2**	**10.81**
Cladocera	81.15	39.13	40.7	7.3
Copepode	72.1	28.5	11.34	3.48
Rotifer	14.32	-	1.07	-
Insects	**9.29**	**-**	**2.07**	**-**
Diptera	7.53	-	0.61	-
Chironomid larvae	7.53	-	0.61	-
Plecopetra	3.01	-	0.21	-
Ephmeropetra	6.28	-	0.68	-
Coleoptera	6.27	-	0.34	-
Hemiptera	2.51	-	0.18	-
Fish egg	**0.5**	**-**	**0.02**	**-**
Gastropoda	**0.96**	**1**	**0.08**	**0.04**
Ostracode	**1.5**	**0.1**	**0.1**	**0.05**
Sand particles	**-**	**5.79**	**-**	**0.53**
Detritus	**61.8**	**76.32**	**12.7**	**17.98**
Unidentified matter	**4.02**	**5.79**	**0.19**	**0.25**

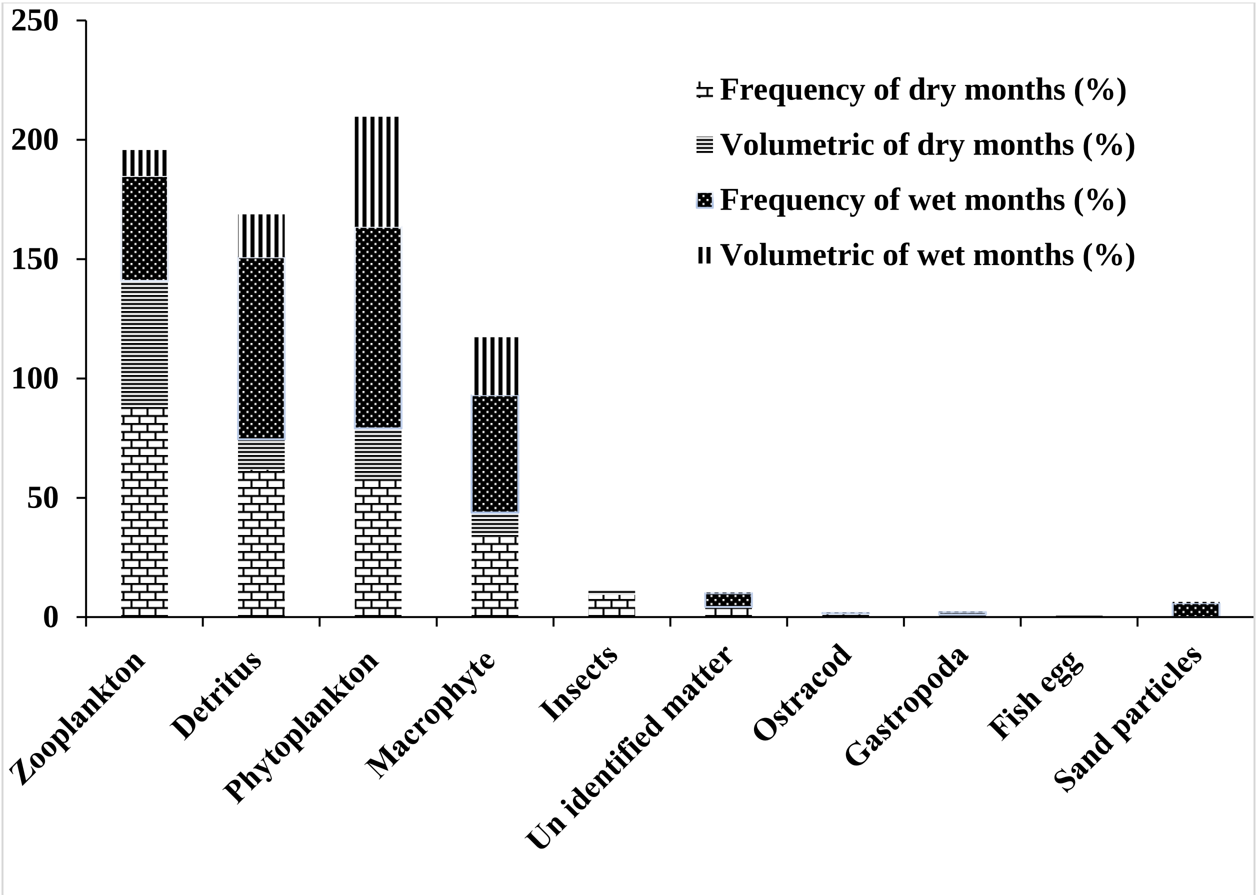

Figure 4.1: Relative contribution of different food items in the diet of *C. carpio* in Lake Ardibo during dry and wet months

4.5. Ontogenic Dietary Shift of *C. carpio*

The diet composition of all size classes of *C. carpio* did not exhibit ontogenic dietary shift during the life history of the fish, all prey organisms (phytoplankton, zooplankton, detritus, macrophyte, insects, ostracode, gastropod, sand particles, fish egg, and unidentified matters) were consumed by all size class except fish egg, sand particle, and ostracod. In the smaller size class (≤ 10 cm), phytoplankton (38.5%), zooplankton (24.2%), detritus (18.33%), and macrophytes (17.3%) constituted most of the volumetric contribution. On the contrary, the contribution of other food items, such as insects (1%), unidentified matters (0.17%), gastropods (0.1%), and sand particles (0.4%), respectively, was comparatively low in comparison with other small size class prey items (Figure 4.2).

In the intermediate size class, (10-22 cm), the volumetric contribution of zooplankton (40.7%), phytoplankton (28.99%), detritus (14.6%), and macrophytes (13.65%) was significantly greater compared to the percentage of different types of food. Conversely, though, insects (1.42%), unidentified matters (0.22%), ostracode (0.1%), gastropods (0.07%), sand particles (0.24%), and fish egg (0.01%) were relatively less important for the intermediate size class (Figure 4.2).

In the larger size class (22-35 cm), the volumetric contribution of zooplankton, which was of intermediate importance to the *C. carpio* diet, decreased to (19.77%). Despite this, the significance of the subsequent prey items like unidentified matters (0.24), insects (0.44%), sand particles (0%), ostracode (0.04%), gastropods (0%), and fish egg (0%) was negligible for this size class (Figure 4.2). On the other hand, the volumetric contributions of detritus were comparable between the intermediate and the larger size classes. Conversely, among the main food items, the volumetric contributions of phytoplankton and macrophytes constituted the most important prey items for the larger size class of *C. carpio* and further grew to 43.29% and 21.08% respectively (Figure 4.2).

Food items of animal origin made up a higher portion in all size classes of the *C. carpio's* diet. Whereas the proportion declined as the fish grew except for the intermediate-size class. Similarly, food of plant origin was present in a larger portion in all size classes. The percentage increased as the fish size grew except intermediate size class.

Table 4.3: Schoner Diet Overlap Index (SDOI) in three size classes of *C. carpio* from Lake Ardibo

Size classes	**SDOI Value**
Lower (≤ 10 cm TL) and intermediate (10-22 cm TL)	0.81
Intermediate (10-22 cm TL) and higher (22-35 cm TL)	0.78
Lower (≤ 10 cm TL) and higher (22-35 cm TL)	0.91

Note: TL = Total length

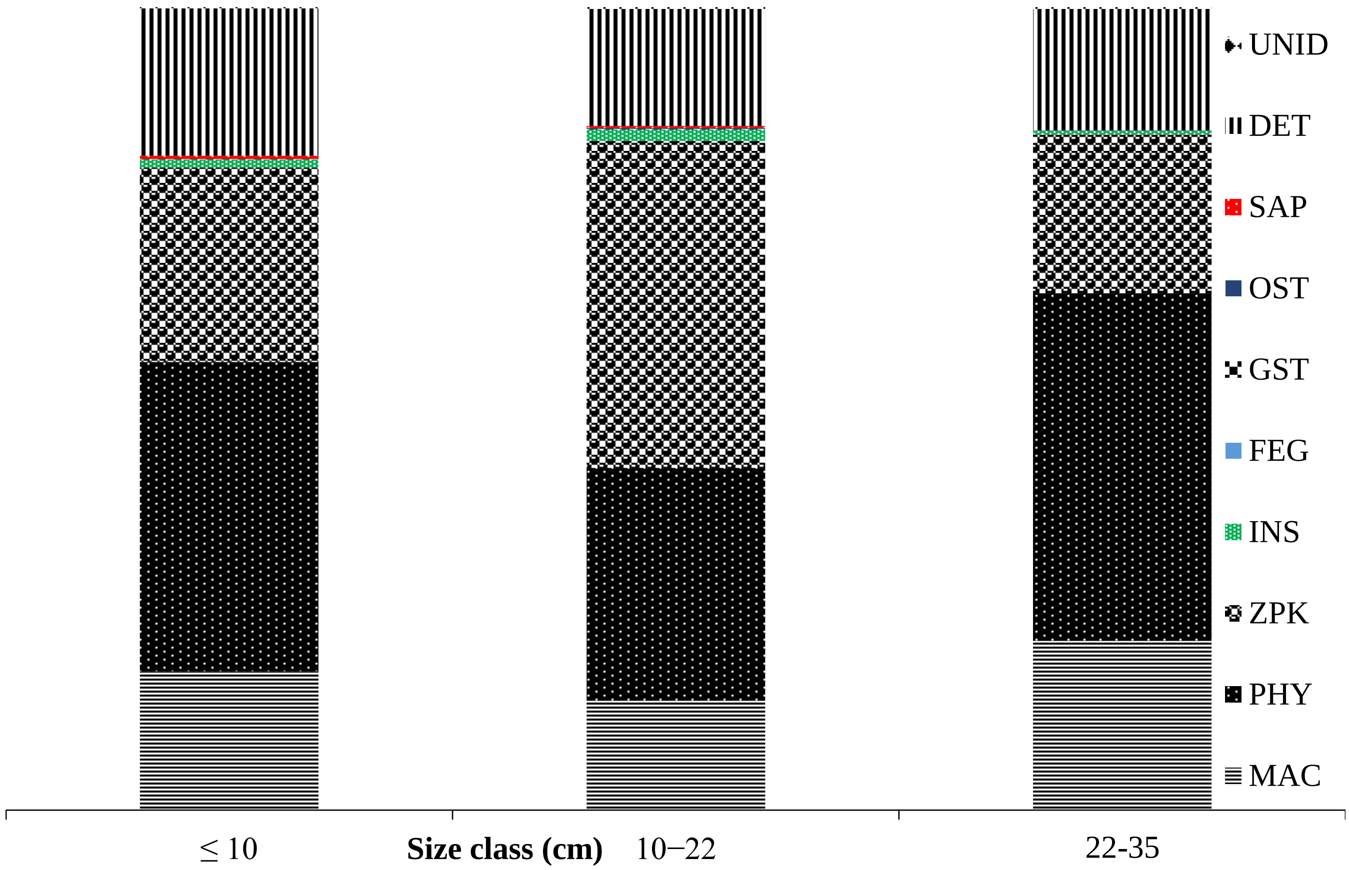

Figure 4.2: The relative volume of prey organisms consumed by different size class *C. carpio* (n = 605) from Lake Ardibo (UNID- unidentified matters, DET- detritus, SAP- sand particles, OST- ostracode, GST- gastropods, FEG- fish egg, INS- insects, ZPK-zooplankton, PHY- phytoplankton, MAC- macrophyte).

CHAPTER FIVE: DISCUSSION

5.1. Sex Ratio

In the current investigation, the number of male *C. carpio* was higher than that of females. This result is supported by the idea of Aera *et al*. (2014), who report a sex ratio of 1.63:1 (male: female) for *C. carpio* in Lake Naivasha. Likewise, the study is also in line with Mert and Bulut (2014), who stated that a female-to-male ratio of 1.53:1 in Damsa Dam Lake in Turkey. Also, Assefa Tessema *et al*. (2020), reported that the female-to-male ratio from Lake Hayq was 0.77:1 (female-to-male), and there was a significant deviation from the female-to-male ratio, meaning there is 1 male individual present in the population. The significant variation from the male-to-female ratio suggests an imbalance or deviation from an equal sex distribution within the population, with potential implications for mating, reproductive success, and population dynamics. Similarly, the findings agree with Solomon Wagaw *et al.* (2024), who report a sex ratio of 1:0.66 (male: female) for *C. carpio* Lake Arekit.

However, this finding disagrees with Mathewos Hailu (2013) and Lemma Abera *et al*. (2015), who showed that there was no significant variation between the female and male ratios in Amerti Reservoir. This inequality in the proportion of males to females could be due to various factors such as different mortality rates (Quinn and Buck, 2001), and sexual segregation during spawning Mert and Bulut (2014). Also, the unequal proportion of males to females in the population can be influenced by gear types used and differences in fishing sites. This means the choice of gear and fishing locations can play a crucial role in selectively targeting certain sexes of fish. For example, gear types that are more effective in capturing males. During spawning seasons, male fish may display more territorial and active behaviors in the littoral zones, making them more susceptible to capture by fishing gear. In contrast, differences in fishing sites, such as areas where females congregate for spawning or feeding, may result in a higher proportion of female captures. Additionally, the active movement of males in searching for mates and courtship behaviors can make them more vulnerable to fishing, leading to a higher proportion of males being captured compared to females. Also, the disparity in the male-to-female ratio might be due to the result of behavioral distinctions between the sexes, leading to one gender being more susceptible to capture than the other. Additionally, variations in habitat preferences influenced by differing stages of sexual maturity throughout the spawning season may contribute to this imbalance (Solomon Wagaw *et al*., 2022). Additionally, females continue to remain in submerged vegetation for incubation and to protect their young from predators (Gómez-Márquez *et al*., 2003).

5.2. Diet Composition of *C. carpio*

C.carpio has the ability of a species to consume a wide variety of food items using different feeding techniques (versatile feeding behavior) and the one that has a broad diet and can consume a wide range of food types rather than specializing in one specific food item or type (characterized as a generalist) and consumes whatever food is most readily available at the time, rather than seeking out specific types of food. An omnivore is an organism that eats both plant and animal material (opportunistic omnivore) (Mustafizur *et al*., 2010; Dam *et al*., 2018). The diet composition found in this work also demonstrated a high diversity of food items. This suggests that the species takes advantage of most available food items. Notable differences have been found in the diet composition of this species in different water bodies which suggests a close relationship with the local fauna and flora (Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; AssefaTessema *et al*., 2020).

In the result, the present study revealed that food items identified in the diet of *C. carpio* were composed of macrophyte, phytoplankton, zooplankton, insects, fish eggs, gastropods, ostracode, sand particles, detritus, and unidentified matter and it can be considered polyphagous. Similar findings for the same fish species from other water bodies were reported by different authors (Kassahun Assaminew, 2005; Saikia and Das, 2009; Elias Dedabo *et al*. (2015) for Lake Koka; Abebe Tesfaye *et al*.(2020) for Lake Ziway; Assefa Tessema *et al*. (2020) for Lake Hayq.

In the current investigation, in terms of prey preference, food items of animal origin particularly zooplankton were one of the main food items ingested by *C. carpio*. This result is agreed with the study done by Adámek *et al*. (2003), Rahman and Meyer (2009), and Dulic *et al*. (2015). Likewise, as reported by Abebe Tesfaye *et al*. (2020) from Lake Ziway, the majority of the food items in *C. carpio's* diet were comprised of zooplankton. According to Summerfelt *et al*. (1971) observed that the predominant food of *C. carpio* in Oklahoma Reservoirs comprised detritus and zooplanktonic (Cladocera, copepod, and benthic macro-invertebrates (Diptera)). In addition, the findings of Saikia and Das (2009) in rice fields in Apatani Plateau of Arunachal Pradesh (India) revealed that the gut contents of *C. carpio* encompassed zooplankton (Cladocera, copepode, rotifer), algae, benthic organisms (Diptera, mostly Chironomidae larvae and ostracods), plant residues, and mud. Magalhães (1993) noted that zooplankton, phytoplankton, detritus, and mud were identified in the digestive tract of *C. carpio*. Additionally, according to Ali *et al*. (2010) in Turkey's Hirfanli Dam; zooplankton, benthic organisms, and green algae were apparent in the gut of *C. carpio*. In the present study, zooplankton comprised 36.27% of the total dietary volume of *C. carpio*, underscoring its significant contribution to the *C. carpio* diet. Similarly, the result is in line with the report of Ali *et al*. (2010).

Cladocera was the most relevant prey organism for the *C. carpio's* diet among the zooplankton taxa. The significant amount of Cladocera that *C. carpio* consumes might be caused by the high biomass and abundance of Cladocera in the lake, especially during the dry months. This finding has been supported by the findings of Magalhães (1993). The current study showed that rotifers represented only a small percentage of the *C. carpio* diet in Lake Ardibo. This might be a result of the smaller size of rotifers when compared to Cladocerans and copepods. The law of optimal foraging may also help to explain why the fish chose the larger zooplanktons over the smaller ones based on their net energy gain (Zaganini *et al*., 2012). The other most probable cause of the low biomass of rotifers might be because rotifers were immediately digested by the *C. carpio* in their gut (Sutela and Huusko, 1997). This study agrees with other investigators results (Kassahun Assaminew, 2005; Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; and Assefa Tessema *et al*., 2020). Despite this, the reports of Elias Dedabo *et al*. (2015); Abebe Tesfaye *et al*. (2020); and Assefa Tessema *et al*. (2020), showed that the contribution of zooplankton to the *C. carpio* diet was low in other Ethiopian lakes; this might due to the low abundance and biomass of zooplankton in those water bodies.

The present result showed that phytoplankton, which consists of diatoms, particularly *Cymbella*, *Navicula*, and *Aulacoseria* spp., blue-green algae (microcyst), and green algae (*Scenedesmus*, *Co smarium*, and *oocyst* spp.) were identified to be the second most important food source for *C. carpio*. Therefore, the high contribution of phytoplankton to the *C. carpio* diet might be because of the high biomass of phytoplankton per square meter in the lake. The other possible reason for the high contribution of phytoplankton to the *C carpio* diet might be due to the presence of phytoplankton in the diet of *C. carpio* may be influenced by complex trophic interactions within the lake ecosystem, where phytoplankton forms the base of the food chain and supports higher trophic levels, including fish like *C. carpio*. This finding is supported by Karaca (1995) in Ankara who reveals that Chrysophyta represented the lion's share of 55.46%. Likewise, the study is supported by Maitland (1992) who claims that *C. carpio* demonstrates a diversified diet, encompassing plant matter, detritus, and benthic organisms in its feeding preferences. Also, the result is consistent with Njiru *et al*. (2006) in Lake Naivasha who stated that *C. carpio* consumes surface-dwelling aquatic plants. However, the contribution of phytoplankton was low to the *C. carpio* diet (Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; and Assefa Tessema *et al*., 2020).

From the identified phytoplankton, Egulenoid occurred in 1.48% of the stomach and volumetrically contributed to 0.1% of the outcome of the current study. This result agreed with Abebe Tesfaye *et al*. (2020) and Assefa Tessema *et al*. (2020). From observed phytoplankton, dinoflagellates occurred 8.92% of the gut and 0.82% of the volumetric contribution to the fish's diet. This result is agreed with the report of Assefa Tessema *et al*. (2020). The presence of euglenoids and dinoflagellates in the *C.carpio's* diet might be due to a direct link to the phytoplankton composition of the lake. These phytoplankton groups may be likely part of the *C.carpio* diet due to their availability and nutritional value, leading to their ingestion by the fish species. The seasonal fluctuations in phytoplankton composition support the variability in available food sources for *C.carpio*, potentially resulting in the consumption of euglenoid and dinoflagellates during specific periods. Despite this, the other investigations done by Elias Dedabo *et al*. (2015); Abebe Tesfaye *et al*. (2020); and Assefa Tessema *et al*. (2020) noted that the phytoplanktons had a minor contribution to the *C. carpio's* diet. Also in some previous studies done by Elias Dedabo *et al*. (2015) in Lake Koka, and Abebe Tesfaye *et al*. (2020) in Lake Ziway; dinoflagellates were not identified in the diet of the fish.

In the current investigation, *C. carpio* exhibited a substantial consumption of detritus within the ecosystem of Lake Ardibo, establishing detritus as the 3rd predominant food item among the various prey organisms identified. This result is consistent with several authors results (Kassahun Assaminew, 2005; Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; Assefa Tessema *et al*., 2020). The high presence of detritus in the diet of *C. carpio* could be attributed to their anatomical adaptations, including wider mouth gaps and a well-developed digestive system with a sophisticated array of digestive enzymes, complemented by extended and enlarged gut lengths. These physiological characteristics enable the fish to proficiently digest complex organic materials that may have been indigestible during their younger developmental stages. This preference for detritus, particularly derived from plant sources rich in lignin, is influenced by their digestive capabilities. The breakdown of lignin, a complex plant compound, in detritus, provides *C. carpio* with additional energy and essential nutrients that support their growth and health, thereby increasing the contribution of detritus to their overall diet. The high level of detritus found in the guts of *C. carpio* may be evidence of its broad spectrum of ecological adaptation. Since detritus originates from different food items and does not create a single, homogenous feed supply, detritus feeding habits were frequent among omnivores (Dam *et al*., 2018).

In the current study, the presence of a high level of detritus might be due to the lake having a lot of floating and emergent water plants as well as partially decomposed leaves and animals. In addition, *C. carpio* was known to be an opportunistic feeder ingesting a variety of prey items (Mustafizur *et al*., 2010). The presence of detritus in the *C. carpio's* gut suggested their ability to consume this food source efficiently, possibly due to their feeding behavior that allows the fish to scavenge the bottom for food. Also, the other possible reason *C. carpio* lacked a true detritus-recycling stomach, is that they may have consumed detritus while foraging on benthic organisms. This anatomical feature (the gastrointestinal tract) may be attributed to the dominance of detritus in their diet (Elias Dedabo *et al*., 2015).

The current result revealed that macrophytes constituted the most prevalent prey item in *C. carpio*'s diet in Lake Ardibo. This may be related to the availability of macrophytes in the lake as well as the abundance of emergent and floating water plants. The other possible reason could be to *C. carpio* is known to be an opportunistic feeder, consuming a variability of food sources based on availability and nutritional content, meaning they consume a wide variety of food sources based on availability and nutritional content. When dealing with opportunistic feeding, it is essential to consider the selective nature of the feeding behavior to optimize dietary intake and overall nutrition. This involves understanding the fish's preferences, monitoring food availability, and ensuring a balanced diet that meets their nutritional requirements (Dam *et al*., 2018). *C. carpio* is a benthic feeder and may disturb the sediment to uproot plants, which can result in a higher intake of macrophytes. The species might also consume macrophytes while feeding on benthic invertebrates that live with the vegetation (Rahman *et al*., 2009). Also, this may be due to there being few other herbivorous fish species in the lake, facing little competition for macrophytes and allowing them to consume these plants more freely. It is also reported that macrophytes were not more consumed by herbivores (Burks and Lodge, 2002).

Additionally, the structure of macrophytes provides hiding places for other prey organisms, making them easily accessible for *C. carpio* to feed on. Macrophytes, may a crucial role in freshwater ecosystems by offering structural complexity and habitat for various organisms. This structural complexity can influence the feeding habits of *C. carpio* and it provides shelter and protection for small invertebrates, juvenile fish, and other prey organisms. The dense foliage offers a safe refuge from larger predators. The *C. carpio* use macrophytes as breeding grounds. During that, the plants offer surfaces for egg attachment and protection for juveniles. While macrophytes provide hiding spots, they also create an environment where prey organisms are concentrated and relatively confined. This makes it easier for *C. carpio* to locate and feed on them. This finding is in line with those reported by different authors (Saikia and Das, 2009; Elias Dedabo *et al*., 2015; Abebe Tesfaye *et al*., 2020; Assefa Tessema *et al*., 2020). In accordance with Rahman *et al*. (2010), *C. carpio* tends to migrate to locations with higher availability of nourishment in their natural environment. The wider mouth gaps and more advanced digestive system, with more developed digestive enzymes, along with the longer and greater gut length of *C. carpio*, might be contributing factors to the higher proportion of macrophytes in their diet. This enables the fish to process more complex food items that might be indigestible at juvenile stages (Flipos Engdaw *et al*., 2013)

In the current investigation, insects were the lowest contributor to the *C. carpio's* diet, occurring at a frequency of 6.11% and a volumetric contribution of 1.23%. However, research done on other water bodies by Kassahun Assaminew (2005); Njiru *et al*. (2006); Saikia and Das (2009); Elias Dedabo *et al*. (2015); Abebe Tesfaye *et al*.(2020); Assefa Tessema *et al*. (2020) the contribution of insect to the *C. carpio's* diet was higher than the result of the present study. This might be due to the reason the lake's environment is not conducive to the reproduction of insects. Another reason may be due to seasonal fluctuations in insect populations that were not captured during the study period. During the dry season, water levels in lakes often decrease. This may result in habitat loss for many aquatic insects, which depend on specific conditions for breeding and survival of insects. Higher temperatures during the dry months can affect the reproductive cycles of insects. Some species may not reproduce or survive well in warmer water, leading to reduced their populations. Also, the lower water levels and higher temperatures can lead to poor water quality in the lake. Conditions such as lower dissolved oxygen levels and higher concentrations of pollutants or nutrients in the lake may be harmful to insect larvae and adults. The physical changes to the lake environment, such as dried-out edges and reduced aquatic vegetation, can affect insect breeding sites. Many insects lay eggs in or near water, and these conditions can make it difficult for them to reproduce successfully. With fewer insects available, *C. carpio* may shift their diet to other available food sources, such as plant material, detritus, or other aquatic invertebrates. Also, insect availability can greatly depend on the time of year. In addition, *C. carpio* ingested fewer insects in their diet might be due to their omnivorous feeding behavior (Mustafizur *et al*., 2010). The feeding habits of C. *carpio* were influenced by factors like the availability of food sources, the nutritional content of different prey items, and the ecological conditions of their habitat.

In the present research work, the fish egg contributed a minor importance to the diet of the fish. This result agreed with Elias Dedabo *et al*.(2015); and Abebe Tesfaye *et al*.(2020), which suggested that the fish eggs were found within the stomach of *C. carpio.* Likewise, gastropods, ostracods, and sand particles were of insignificant importance to the *C. carpio*'s diet both during wet and dry months. The lower contribution of ostracode and gastropods might be due to the higher availability of other alternative food sources in the lake that *C. carpio* prefers, which reduces their reliance on ostracode and gastropods. This result is endorsed with Elias Dedabo *et al*. (2015); and Abebe Tesfaye *et al*. (2020).

5.3. Seasonal Variation in the Diet of *C. carpio*

The current findings revealed that there was a notable seasonal variation in the frequency of occurrence of *C carpio*'s diets during the dry and wet months. Similarly, the volumetric contribution of different food categories is significantly different during the dry and wet months (U, t-test, $p < 0.05$, Table 4.3, Figure 4.2). This seasonal variation could be because of the opportunistic feeding nature of *C carpio*, which can shift from one diet to another. These seasonal variations might be stated by the fish shifting its location at certain periods (Ali *et al*., 2010).

In the results of the current investigation, primarily zooplankton, phytoplankton, detritus, and macrophyte were the dominant food items in the *C. carpio's* diet during dry months in Lake Ardibo.

Conversely, during wet months, phytoplankton macrophytes and detritus were more important food items. The alterations are indicative of the seasonal changes in the accessibility and abundance of various food sources in the environment, which affect *C. carpio*'s feeding habit all year round. The difference in the appearance and accessibility of diverse prey items during the wet and dry months could be the cause of this change in the proportion of various prey items.

In the present findings, zooplankton has been identified in the *C. carpio's* diet during both the wet and dry months. The current result confirmed that the most significant food source was zooplankton for the *C. carpio* diet during dry months. This study is endorsed by the report of Ali *et al*. (2010) in Hirfanli Dam Lake Ankara; Manon and Hossain (2013) in University of Rajshahi; Shukla and Patel (2013) in Govindgarh Lake; Naik and Rashid (2015) in Dal Lake of Kashmir Valley; Abebe Tesfaye *et al*. (2020) in Lake Ziway. From the zooplankton taxonomic group, Cladocera, copepod, and rotifer represent comparatively the most significant prey items. However, both the volumetric contributions and frequency occurrence of zooplankton to *C. carpio* diets were decreased during wet months. The low contribution of zooplankton during the wet months could be the cause of the low biomass and low abundance of zooplankton during wet months. In aquatic ecosystems, zooplankton are often preyed upon by fish and other organisms. During the wet months, when water levels may be higher and more predators might be present, zooplankton populations may face increased predation pressure, leading to lower biomass and abundance. Also, due to increased rainfall can lead to higher water turbidity, which could affect the *C. carp's* ability to visually locate zooplankton. The other probable reason might be the wet months can bring about changes in the habitat structure, such as increased vegetation, which can affect the distribution of zooplankton and the feeding patterns of *C. carpio*. This finding is in line with studies done by Elias Dedabo *et al*. (2015); Abebe Tesfaye *et al*.(2020); Assefa Tessema *et al*. (2020). Despite this, the findings of Saikia and Das (2009), and Ali *et al*. (2010) showed that Cladocera and copepods constituted the most prevalent zooplankton food items in the *C. carpio's* diet during the wet months.

The contribution of rotifers is relatively low both in terms of volumetric contribution and frequency of occurrence in dry months. This might be due to the rotifers being immediately digested in the gut of *C. carpio*. This result is in line with Saikia and Das (2009), Ali *et al*. (2010), Elias Dedabo *et al*. (2015), and Abebe Tesfaye *et al*. (2020). However, rotifers were not found in the *C. carpio* gut during the wet months. This result is in line with Elias Dedabo *et al*. (2015). This could be due to variations in the number of zooplankton that the groups consumed in the wet and dry months, as well as variations in the reproductive cycles of the groups that could be impacted by temperature and other environmental factors (Elias Dedabo *et al*., 2015).

In the current study, phytoplankton were identified during both wet and dry months. This study is in line with Elias Dedabo *et al*. (2015) in Lake Koka; Abebe Tesfaye *et al*. (2020) in Lake Ziway; and Assefa Tessema *et al*. (2020) in Lake Hayq. While phytoplankton comprised the largest portion of the *C.carpio's* diet during the dry months, accounting for 57.5% of stomach contents and 21.5% of the total food volume, its contribution significantly increased during the wet months, reaching 84.5% and 46.1% of the total volume. During dry months, diatoms were the most significant food items in the *C. carpio* diet. However, green algae were the significant prey item in the *C. carpio* diet during the wet months, despite its contribution was little during the dry months.

The contribution of phytoplankton dominance during the wet months in the *C. carpio* diet might be because the wet months typically bring increased nutrient inputs into the lake through runoff, and human activities leading to higher nutrient availability; due to this phytoplankton biomass might be increased (Smith and Schindler, 2009). This abundance of nutrients can promote the growth of phytoplankton contributing more to its volumetric contribution and frequency of occurrence in the present investigation. Also, the warmer water temperatures and increased sunlight during the wet months create favorable conditions for the growth and proliferation of algae. Higher temperatures and longer daylight hours enhance photosynthesis and metabolic activities, supporting the growth of phytoplankton (Desenerpont *et al.*, 2013). In contrast to this, the significance of phytoplankton in other studies during the wet and dry months like in Lake Koka by Elias Dedabo *et al*. (2015); in Lake Ziway by Abebe Tesfaye *et al*. (2020); Lake Hayq by Assefa Tessema *et al*. (2020) was negligible to the the fish's diet as compared to the current result.

In the current work, the frequency occurrence of detritus was comparable among months being relatively higher in wet months. This result was agreed with Abebe Tesfaye *et al*. (2020). Despite this, its volumetric contribution increased in the wet months than dry months. It is found in 61.8% and makes up 12.7% of the total volume of food items in the dry months. However, the frequency occurrence of detritus was 76.32% and its volumetric contributions increased to 17.98% of the entire volume of prey items in wet months. Therefore, the highest detritus volumetric contribution to *C. carpio's* diet could be caused by the wet months typically involving higher levels of precipitation, leading to increased runoff from the surrounding land into the lake. This runoff can carry organic matter, which breaks down into detritus, increasing its availability in the water (Abebe Tesfaye *et al*., 2020). The other reason might be heavy rains and inflows during the wet months can stir up the lake's bottom sediments, resuspending detritus into the water column where it becomes more accessible to bottom-feeding fish like *C. carpio* (Elias Dedabo *et al*., 2015). Also, the additional probable cause due to the rising water levels during the wet months can flood new areas, such as vegetated shorelines, which are rich in organic matter that decomposes into detritus. *C.carpio* might exploit these new feeding grounds. Also, it is known to be an opportunistic feeder (Rahman *et al.,* 2010). It may be also detritus that becomes more palatable or easier to process during the wet months, and C. *carpio* might selectively feed on it. This result is consistent with the findings of Elias Dedabo *et al*. (2015) in Lake Koka; Assefa Tessema *et al*. (2020) in Lake Hayq; and Abebe Tesfaye *et al*.(2020) in Lake Ziway.

During the current investigation, based on the frequency of occurrence, macrophytes were comparable among months being relatively higher in wet months. This agrees with the findings of Abebe Tesfaye *et al*. (2020). However, its volumetric contribution varied significantly. During the wet months, it accounted for 49.3% of the stomach and 24.24% of the entire volume of food items. The highest volume of macrophytes in the current study may be due to the wet season typically bringing higher water levels, which can flood areas with rich vegetation, including macrophytes. This expansion of habitat can provide *C. carpio* with increased access to macrophytes. *C. carpio* might change its feeding behavior based on the seasonal availability of food sources. Macrophytes were available during the wet season, this might be due to *C. carpio* was consume them more frequently. The extra possible reason might be due to the wet months coincide with the *C. carpio*'s spawning period, they might be more likely to be found in vegetated areas where macrophytes are abundant, leading to a higher intake of plant material (Elias Dedabo *et al*., 2015; Vonbank *et al*., 2018). Also, macrophytes grow all year round in lakes and are easily accessible by fish (Abebe Tesfaye *et al*., 2020). This finding agreed with Elias Dedabo *et al*.(2015; Assefa Tessema *et al*.(2020). Despite this, research done by Abebe Tesfaye *et al*. (2020) in Lake Ziway the consumption of macrophytes by *C. carpio* remained consistent throughout both the dry and wet months, with similar proportions found in their stomach contents and total food volume. The outcome of the present finding showed that during the dry months alone, insects were the least essential food item. It comprised 2.07% of the entire volume of prey items and was found in 9.29% of stomachs during the dry months. *C.carpio* might be attracted to other prey items like zooplankton, phytoplankton, detritus macrophytes, and other common prey items in the environment. An increase in temperature can also contribute to an abundance of insects (Elias Dedabo *et al*., 2015). Conversely, the contribution of insects was absent in the wet months. This might be due to insects being more abundant and accessible to *C. carpio* during the dry months when environmental conditions favor their presence. During the wet months, insects were completely absent from the *C. carpio's* diet. This may be related to the dilution effect of increased water volume during the wet months, which may disperse insect populations and make them less accessible to foraging. In addition, *C. carpio* may adjust their feeding preferences based on seasonal variations in food availability. During the wet months, when other food sources like phytoplankton, detritus, and macrophytes are more prevalent, *C. carpio* may prioritize these items over insects in its diet. However previous studies done by Abebe Tesfaye *et al*. (2020) and Elias Dedabo *et al*. (2015) showed that the contribution of insects was higher than the present finding and it was the most essential prey item during dry months.

Sand particles were the least significant food item to the diet in the current finding during the wet months, while they did not contribute at all during the dry months. This might be due to seasonal changes in nutrient availability can influence the feeding preferences of *C. carpio* (Klefoth *et al*., 2013). The wet months, characterized by increased rainfall and runoff, may introduce a higher quantity of organic matter and nutrients into the lake, including sand grains that could serve as a food source for the *C. carpio*. As a result, *C. carpio* might accidentally ingest more sand particles along with their intended food due to reduced visibility and the suspension of more particles in the water. Sand particles in the food items might be because of browsing on the dead organic matter. The adhering sand particles would have been accidentally present along with detritus or this is an indication that these species are bottom feeders (Shawardi, 2006).

On the other hand, ostracode and gastropod contributions to the *C. carpio's* diet were similar in dry and wet months in the present study. Gastropods and ostracods were insignificant importance food items, and their contribution was low during wet and dry months. This could be attributed to the comparatively lower nutritional value provided by gastropods and ostracode in comparison to alternative food sources such as phytoplankton, zooplankton, or detritus, prompting *C. carpio* to favor more nutritionally abundant choices. This might be because *C. carpio* is an opportunistic feeder, and its diet can vary based on the local availability of food sources (Rahman *et al.,* 2010). If other preferred or more available prey organisms were available in the lake, *C. carpio* may consume fewer ostracode and gastropods. This result is endorsed by Elias Dedabo *et al*. (2015).

5.4. Ontogenic Dietary Shift of *C carpio*

In the current finding, the Schoener Diet Overlap Index (SDOI) value in the diets of *C. carpio* between size classes I and II (SDOI = 81%) for lower size (≤ 10 cm TL), II and III (SDOI = 78%) for intermediate size class (10-22 cm TL), and I and III (SDOI = 91%) for higher size classes (22-35 cm TL) of *C. carpio*. This information is crucial for understanding how dietary preferences and feeding habits may vary among different size classes of *C. carpio*, shedding light on their ecological interactions and resource utilization patterns within their environment. Therefore, the percentage overlap of the SDOI values surpassed 0.60. This significant overlap value suggests a considerable commonality in the dietary preferences and food items ingested by the three size classes of *C. carpio*. This outcome is in line with the research done by Elias Dedabo *et al*. (2015) for Lake Koka; and Abebe Tesfaye *et al*. (2020) for Lake Ziway. On the other hand, a study done by Assefa Tessema *et al*. (2020) in Lake Hayq revealed that a minor ontogenic dietary shift was seen in a lower-size class with the same species.

In the present examination, the diet composition of *C. carpio* indicated that an ontogenic dietary shift was not noted in the prey organisms consumed by *C. carpio*. The volumetric contribution of major food items of *C. carpio* occurred in the diet of all size classes except fish egg, sand particles, and gastropods was absent in higher size classes. However, the volumetric proportion of major food items was different in all size classes. The relative importance of zooplankton declined with the increased fish size except in the intermediate size class. The volumetric contribution of zooplankton was more abundant in the diet of the intermediate-size class (10-22 cm TL) as compared to the smaller-size class (Juveniles). This may be due to zooplankton abundance and accessibility can vary with depth and water column stratification (Chen *et al.*, 2022). Lower-sized *C. carpio* (≤ 10 cm TL), being more restricted in their movement and foraging range, may primarily feed on zooplankton that is more abundant and accessible in the upper layers of the water column where they predominantly reside (Rahman *et al*., 2009). The intermediate-size classes (adults) may also consume more zooplankton as they transition to a more varied diet. The other probable reason might be the intermediate-size class of *C. carpio* is at a stage where their body is growing rapidly, and they require a diet that can support their growth. Zooplankton are an excellent source of protein and essential nutrients. Which are vital for the development of tissues and organs. The *C. carpio* feeding apparatus at this stage is optimally adapted for capturing and processing zooplankton. This makes zooplankton an efficient food choice that fulfills their dietary needs for rapid growth without expending excessive energy in foraging. Moreover, investigations were done by Elias Dedabo *et al*. (2015) for Lake Koka; Abebe Tesfaye *et al*. (2020) for Lake Ziway; AssefaTessema *et al*. (2020) for Lake Hyaq zooplankton was highly ingested by smaller sized *C. carpio*.

In the present work, in higher-size classes (22-35 cm TL), lower zooplankton were encountered. This could be because of the capability of foraging in deeper waters, *C. carpio* prioritizing other food sources, and their larger size and energy requirements. This outcome agrees with the findings made by Elias Dedabo *et al*. (2015); and Abebe Tesfaye *et al*. (2020).

The result of the current study revealed that detritus was ingested as the major food item in all size classes with little differences. This might be because the consumption of detritus by *C. carpio* contributes to nutrient cycling and ecosystem functioning in aquatic ecosystems. Comparable consumption of detritus among different size classes may contribute to the stability and functioning of the aquatic food web by maintaining nutrient fluxes and supporting secondary production. However, a study conducted by Elias Dedabo *et al*. (2015), Abebe Tesfaye *et al*. (2020), and Assefa Tessema *et al*. (2020) showed that detritus was dominantly preferred by higher-sized classes of *C. carpio*.

The volumetric contribution of phytoplankton and macrophytes growing up as the size class of *C. carpio* increases except in the intermediate size class (10-22 cm TL). The contribution of phytoplankton and macrophytes slowly encountered in intermediate size class may be due to growth gain, causing a natural transition from a diet predominantly consisting of phytoplankton to one that includes larger, more energy-dense food sources. This shift is driven by the changing nutritional needs associated with their growth. Also, intermediate-sized classes might occupy different habitats than smaller-sized ones such as deeper waters or areas with more complex vegetation, where larger prey types were prevalent, and phytoplankton was less accessible. This result is supported by the ideas of Elias Dedabo *et al*. (2015); Abebe Tesfaye *et al*. (2020); and Assefa Tessema *et al*. (2020).

In addition, the lower-sized *C. carpio* tend to consume more phytoplankton and macrophytes could be due to their feeding preferences and habitat use. As fish grew, its diet shifted towards different food sources, leading to variations in consumption patterns among different size classes. Phytoplankton and macrophytes might be more abundant and widely distributed in the water column, making them easily accessible for smaller fish like lower-sized *C. carpio* to feed on compared to zooplankton which may require more specialized foraging behavior. Its feeding habits are more focused on these primary producers. Ingestion of phytoplankton and macrophytes was medium at intermediate size classes this might be due to the transition to other food sources. Also, the shift towards medium ingestion of phytoplankton and macrophytes at intermediate size classes suggests a transitional phase in the fish's diet, where they may gradually diversify their feeding habits to incorporate a broader range of plant-origin prey items alongside other food sources. The dominance of higher-size classes in consuming phytoplankton and macrophytes may be attributed to factors like competition for resources and the availability of preferred food sources. The higher-size class of *C. carpio* may outcompete lower-sized individuals for these food items, leading to their increased consumption of phytoplankton and macrophytes in the ecosystem. The omnivorous juveniles and adults ingest algae, worms, insect larvae, and plant seeds. Therefore, each size class of fish has its trophic niche since they are feeding on a specific diet (Oyugi, 2012). However, studies done by Elias Dedabo *et al*. (2015); Abebe Tesfaye *et al*. (2020); and AssefaTessema *et al*. (2020), larger-sized *C. carpio* ingested mainly plant-origin food items. From the minor food item, the volumetric contribution of insects, gastropods, and ostracode insects contributed to the minor importance of all size classes of the fish with a little difference. The *C. carpio* might exhibit different foraging behaviors from larger to smaller individuals. It might feed in different habitats or layers of the water column where insects, gastropods, ostracods, and sand particles were less prevalent. This result is in line with the report of Elias Dedabo *et al*. (2015).

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The present study revealed that *C. carpio* ingested different prey organisms in Lake Ardibo such as zooplankton, phytoplankton, macrophyte, detritus, insects, fish eggs, ostracods, gastropods, sand particles, and unidentified matter. The most important food categories identified in the *C. Carpio* di*et* were zooplankton, phytoplankton, and detritus, macrophyte. The remaining prey items were less important within the diet of *C. carpio*.

Seasonal variation in the diet composition was observed. The frequency occurrence of phytoplankton and zooplankton in the diet of *C. carpio* varied significantly. Likewise, the volumetric contribution of phytoplankton, zooplankton, macrophyte, and detritus varied significantly between dry and months. During dry months, zooplankton, phytoplankton mostly diatoms, blue-green algae, macrophytes, and detritus were the most crucial food items. The contribution of zooplankton declined sharply during wet months despite this, the contribution of phytoplankton was increased during wet months. In addition, phytoplankton primarily blue-green algae and green algae, detritus, and macrophytes were the most imperative food items during the wet months.

The Schoener Diet Overlap Index indicated a consistent absence of ontogenic dietary shifts across all size classes of *C. carpio.* The diet of all size classes of *C. carpio* consists both of phytoplankton and zooplankton, it can be considered an omnivorous fish species.

6.2. Recommendations

Based on the current study, the following recommendations are forwarded:

- The present study analyzed only four months of data due to time and budget constraints. Therefore, future investigation is recommended by taking year-round data to investigate more seasonal variations and ontogenic dietary shifts.
- To make Lake Ardibo's fisheries environmentally friendly, the gillnet mesh size should be seriously restricted to 8 cm and above; as well as long-term monitoring on the status of fish species population, spawning season, and reproduction potential must be done.
- A study of the impact of environmental factors and habitat changes on the feeding habits of *C. carpio* and the impacts of *C. carpio* on native species and the overall ecosystem needs to be conducted.
- Engage local communities through education programs about the importance of lake conservation and sustainable fishing practices, community involvement and awareness are critical for the successful implementation of conservation strategies, compliance with regulations, and fostering a sense of stewardship over local resources.
- Collaborating with stakeholders, involving local communities, providing extension services, and securing government support for fishers and fishery associations, especially in financial matters, are essential components for the success of fishery improvement initiatives.
- Adhering to regional and national fishery regulations is fundamental for the sustainable utilization of Lake Ardibo's fishery resources.
- Additionally, fostering community engagement in fishery management and incorporating their positive attitudes into the management framework are crucial recommendations for enhancing the overall effectiveness of fishery conservation and sustainability efforts.

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APPENDIX

Appendix Table 1: Chi-square (X^2) test of frequency occurrence of C. *carpio* diet during dry and wet months

	Observed Value			Expected Value				
Food items	Dry	Wet	Total	Dry	Wet	TOTAL	P- value	X^2
Macrophytes	33.6	49.3	82.9	40.66613	42.23387	82.9	0.120559	14.04996
Phytoplankton	57.5	84.5	142	69.65731	72.34269	142	0.041271	17.51243
Zooplankton	87.68	43.9	131.58	64.54583	67.03417	131.58	5.48E-05	35.20732
Insects	9.29	0	9.29	4.557158	4.732842	9.29	0.001895	26.19877
Fish egg	0.5	0	0.5	0.245272	0.254728	0.5	0.471151	8.639954
Gastropoda	0.91	1	1.91	0.93694	0.97306	1.91	0.968896	2.879093
Ostracod	1.5	0.1	1.6	0.784871	0.815129	1.6	0.258089	11.26335
Sand particles	0	5.79	5.79	2.840252	2.949748	5.79	0.018218	19.95089
Detritus	61.8	76.32	138.12	67.75399	70.36601	138.12	0.310861	10.50911
Unidentified matter	4.02	5.79	9.81	4.812241	4.997759	9.81	0.612873	7.233017
Total	256.8	266.7	523.5	256.8	266.7	523.5	2.803868	153.4439

Appendix Table 2: Mann-Whitney U test of the volumetric contribution of *C. carpio* diet during dry and wet months

Mann-Whitney test for Zooplankton

Test Statistics

	Zooplankton
Mann-Whitney U	8263.000
Wilcoxon W	12449.000
Z	-6.856
Asymp. Sig. (2-tailed)	.000

Mann-Whitney test for Insects

Test Statistics

	Insects
Mann-Whitney U	.000
Wilcoxon W	21.000
Z	-3.083
Asymp. Sig. (2-tailed)	.002
Exact Sig. (1-tailed Sig.)	.002

Test Statistics

Mann-Whitney test for	Microphyte
Mann-Whitney U	2565.000
Wilcoxon W	11476.000
Z	-8.169
Asymp. Sig. (2-tailed)	.000

Mann-Whitney test for Ostracod

Test Statistics

	Ostracod
Mann-Whitney U	4.000
Wilcoxon W	25.000
Z	-.667
Asymp. Sig. (2-tailed)	.505
Exact Sig. (1-tailed Sig.)	.643

Mann-Whitney test for Sand particles

Test Statistics	Sand particles
Mann-Whitney U	.000
Wilcoxon W	78.000
Z	-4.449
Asymp. Sig. (2-tailed)	.000
Exact Sig. (1-tailed Sig.)	.000

Mann-Whitney test for Detritus

Test Statistics

	Detritus
Mann-Whitney U	13153.000
Wilcoxon W	42799.000
Z	-5.333
Asymp. Sig. (2-tailed)	.000

Mann-Whitney test for Fish egg

Test Statistics

	Fish egg
Mann-Whitney U	0.000
Wilcoxon W	3.000
Z	-1.633
Asymp. Sig. (2-tailed)	0.102
Exact Sig. (1-tailed Sig.)	0.333

Mann-Whitney test for Unidentified matter

Test Statistics	unidentified matter
Mann-Whitney U	77.500
Wilcoxon W	213.500
Z	-.864
Asymp. Sig. (2-tailed)	.387
Exact Sig. (1-tailed Sig.)	.397

Test Statistics

	Phytoplankton
Mann-Whitney U	8822.500
Wilcoxon W	33798.500
Z	-9.386
Asymp. Sig. (2-tailed)	.000

Mann-Whitney test for Gastropod

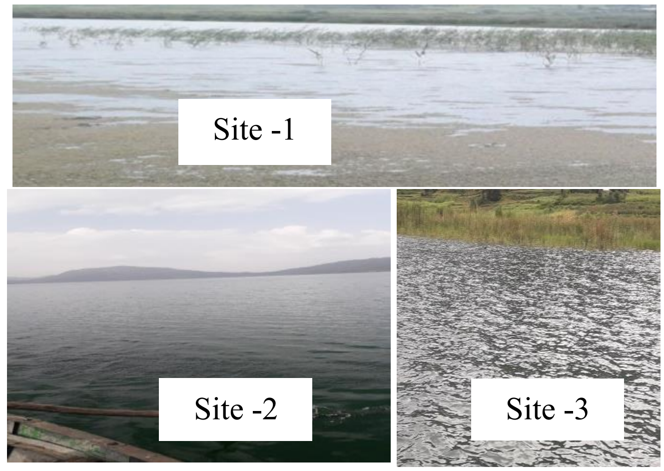
Test Statistics

	Gastropod
Mann-Whitney U	.500
Wilcoxon W	10.500
Z	-1.644
Asymp. Sig. (2-tailed)	.100
Exact Sig. 2(1-tailed Sig.)	.133

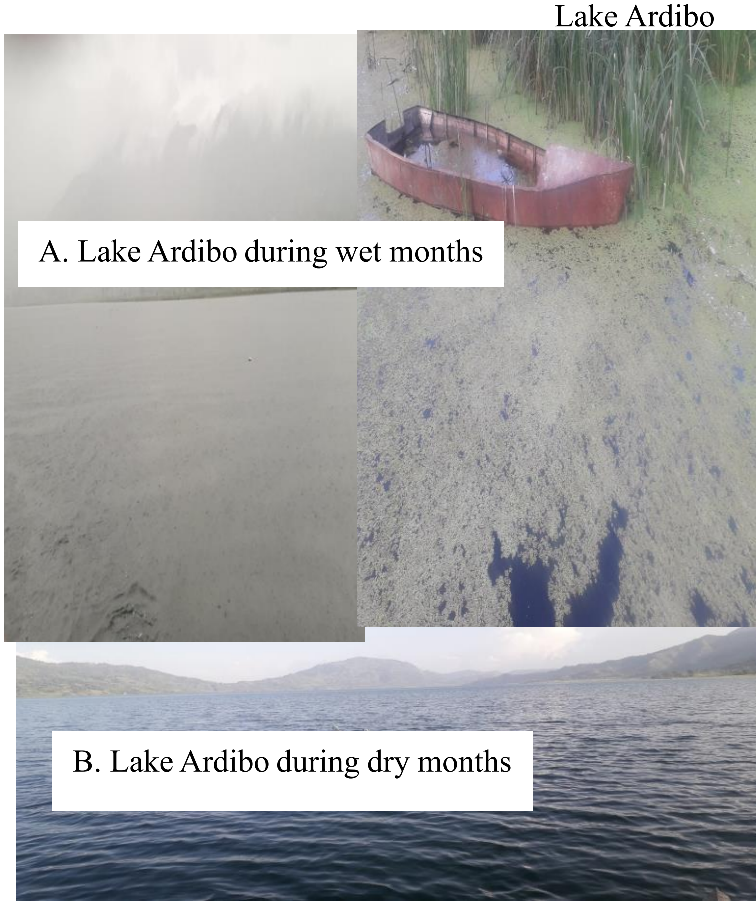
Appendix Table 3: Significance Values of Schoner Diet Overlap Index in the diet of *C. carpio*

Size classes	I	II	III			
Food items	≤ 10	10-22	22-35	I and II	II and III	I and III
Macrophyte	17.3	13.65	21.08	3.65	7.44	3.78
Phytoplankton	38.5	28.99	43.29	9.51	14.3	4.79
Zooplankton	24.2	40.7	19.77	16.5	20.9	4.43
Insects	1	1.42	0.44	0.42	0.98	0.56
Fish egg	0	0.01	0	0.013	0.013	0
Gastropoda	0.1	0.07	0	0.027	0.073	0.1
Ostracod	0	0.1	0.04	0.105	0.07	0.038
Sand particles	0.4	0.24	0	0.16	0.24	0.4
Detritus	18.33	14.6	15.14	3.73	0.54	3.19
Un identified matter	0.17	0.22	0.24	0.05	0.02	0.07
Sum				34.11	44.60	17.36
Significance value				0.83	0.78	0.91

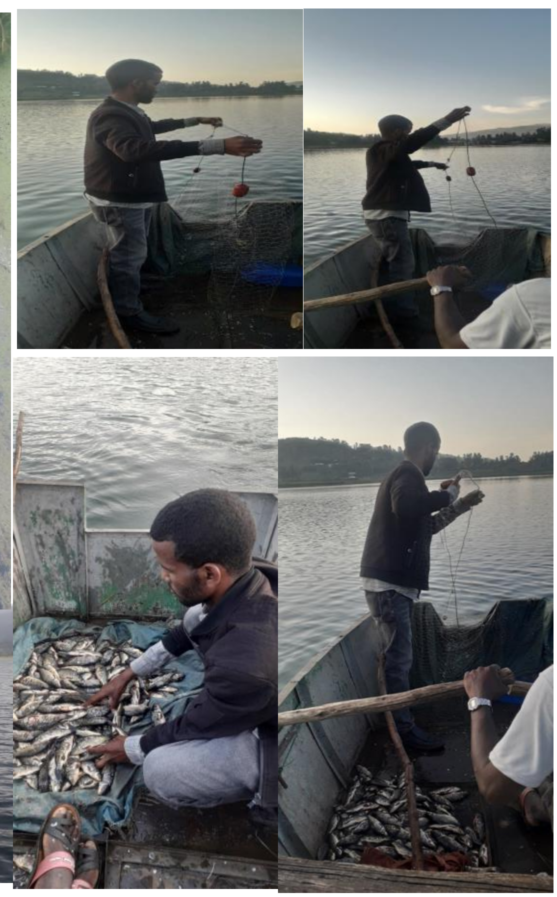
Appendix Figure 1: Aerial view of Lake Ardibo



Appendix Figure 2: Sampling site location on Lake Ardibo



Appendix Figure 3: The variation of Lake Ardibo during wet (A) and dry (B) months (Photos captured by Tilahun Ayalew)



Appendix Figure 4: Setting of gillnets and captured fish during fish sample collection

Appendix Figure 5: Measuring length-weight data and Extracting gut content from *C. carpio* fish species in Lake Ardibo (Photos captured by Tilahun Ayalew)

Appendix Figure 6: Volumetric measurements and identification of *C.carpio* gut content specimens in the laboratory (Photos captured by Tilahun Ayalew)

Appendix Figure 7: Some representative phytoplankton and zooplankton species in Lake Ardibo

Phytoplankton green algae (A, *Coelastrum spp*., C-D, *Cosmarium spp*., F and L’, *Scenedasmus spp*., E, *Clostrium spp*., H, *Tetraedron spp*., B and G, *Pediastrum spp*., I, *Oocysts spp*., P’, Micrasterias spp.) Blue green algae (X, Y, Z, A’, B.’, C’), Diatom (K, J’ and H’, *Aulacoseira spp*., L, *Nitschia spp*., M, *Fragilaria spp*., N, *Diatoma spp*., J, *Thalasiosira spp*., O, S, *Gomphonema spp*., P and V, *Navicula spp*., Q, *Amphora spp*., R, *Rhopalodia spp*., T, *Eunotia spp*., U, *Cymbella spp*., O’, *Epithemia spp. K’ Thelassionema spp*.), Dinoflaglaates (W, *Peridininum spp*.,), Egulenoid (D’, *Phacus spp*.), Zooplankton (I’, N’ and M’, Cladocera; K’ and F’, rotifer; G’, copepod)

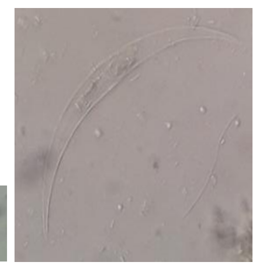
- Some representative phytoplankton and zooplankton species in Lake Ardibo


A

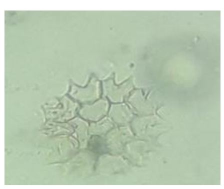

B


C


D


E


F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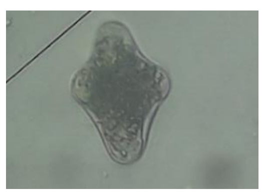
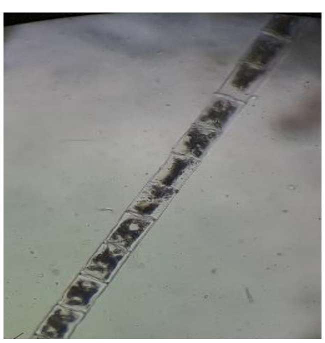
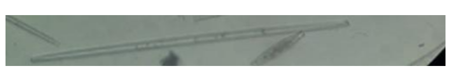

H


I


J


K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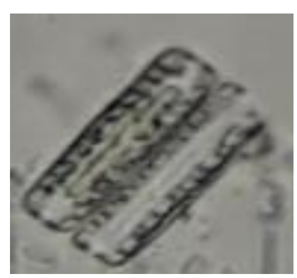
M

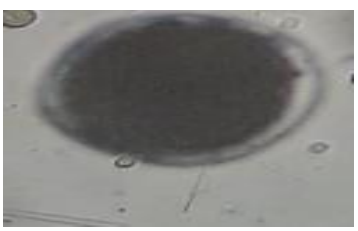
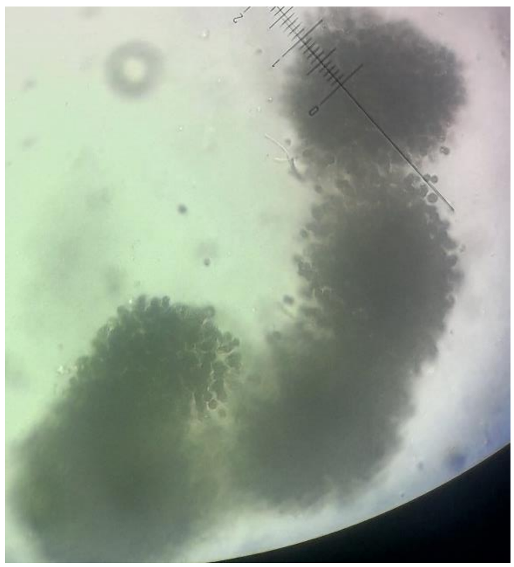
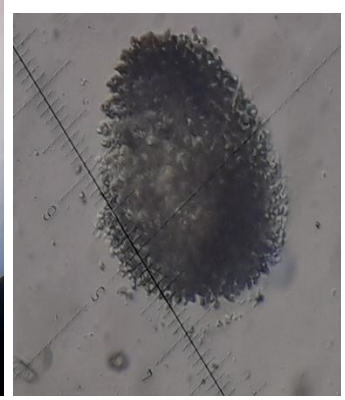

N

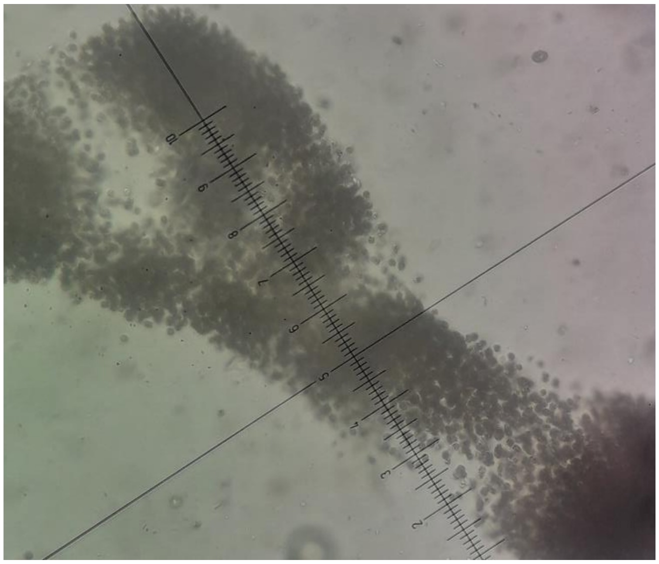
O P Q R

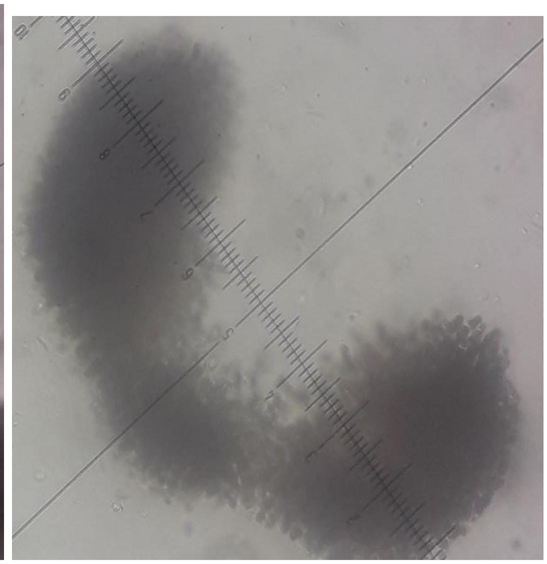
S T U V

W X Z



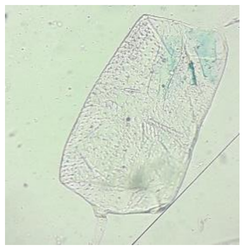
A’

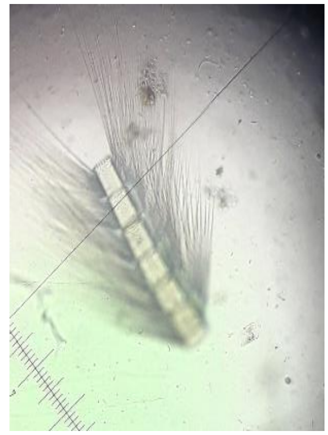


B’

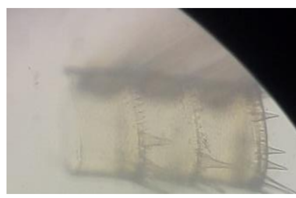
C’

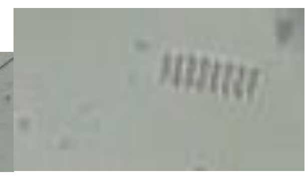
D’

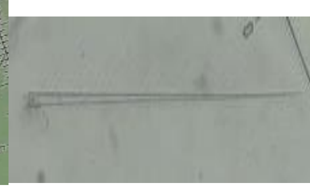


E’ F’ G’ H’



I’ J’ K’ L’

M’ N’ O' P’

AUTHOR'S BIOGRAPHY

Mr. Tilahun Ayalew Demsie was born in July 1992 E.C. in Wuchale 17 Ambassel, South Wollo Zone, Amhara National Regional State of Ethiopia. He attended his primary education at Abet Primary School from 1999-2005 E.C. Then, he moved to Wuchale 17 secondary and preparatory School from 2006-2009 E.C. After successfully passing the Ethiopian Higher Education entrance examination, he joined Assosa University, College of Agriculture and Natural Resources in 2010 E.C. and graduated with a BSc degree in Animal Sciences in 2013 E.C. with a CGPA of 3.97. Upon graduation, he worked at Assosa University as an assistant lecturer for only one year. After serving one year, the university provided an opportunity to earn his M.Sc. degree, and then, he joined the regular postgraduate program at Bahir Dar University, College of Agriculture and Environmental Sciences, School of Fisheries and Wildlife, Department of Fisheries and Aquatic Sciences in January 2014 E.C.