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Agumassie Tesfahun
Department of Biology, Ambo University College of Natural and Computational Science, Ambo, Ethiopia

Mathewos Temesgen
Department of Biology, Ambo University College of Natural and Computational Science, Ambo, Ethiopia

Correspondence
Agumassie Tesfahun
Department of Biology, Ambo University College of Natural and Computational Science, Ambo, Ethiopia

Food and feeding habits of Nile tilapia *Oreochromis niloticus* (L.) in Ethiopian water bodies: A review

Agumassie Tesfahun and Mathewos Temesgen

Abstract
The food and feeding habits of the Nile tilapia *Oreochromis niloticus* was reviewed in Ethiopian water bodies. Data were collected from June 2017 through November 2017 from different sources of information. The results indicated that Nile tilapia is omnivorous, where phytoplankton, macrophytes, insects, detritus and zooplankton were the most important food items. The plant origin foods were the most dominant food item and the seasonal variation in the diet composition is not found in the water bodies except in Lake Koka. Phytoplankton was the most commonly consumed food item in the dry season, whereas macrophytes, detritus, zooplankton and aquatic insects were common in wet season. The fish showed similar trends of different ontogenetic dietary shifts in all water bodies as it increases in size. The small sized groups (<11.5 cm TL) highly preferred to eat the animal origin foods (zooplankton, insect and nematodes), and the larger groups (> 15 cm TL) mainly feed on phytoplankton, detritus and macrophytes. This showed that they are shifting from omnivorous feeding habit to herbivorous feeding habit with increase in size. Generally, the feeding biology of fish is depending on prey availability, season, habitat differences and size of the fish, aspects that might warrant further study in view of aquaculture applications as well as climate change differently.

Keywords: Diet Composition, Feeding habit, Ethiopia, *Oreochromis niloticus*

1. Introduction

Nile tilapia (*Oreochromis niloticus*) is the most important fish species in tropical and subtropical freshwater, often forming a basis of commercial fisheries in many African countries (Mohammed and Uraguchi, 2013) [16]. Its high tolerance to environmental conditions and the ability to accept formulated and natural feeds makes it economically viable (Adeyemi *et al.*, 2009) [1]. It is also one of the most commercially important fish species in Ethiopia (Mitike, 2014) [15]. It contributes about more than 50% of total landings of fish catch per year (Tesfaye and Wolff, 2014) [28]. It is the most widely distributed fish species in the rift valley, Abay, Awash, Baro-Akobo, Omo-Gibe, Tekeze and Wabishebele-Genale basins (Awoke, 2015; Golubtsov and Mina, 2003) [3, 11]. It is also found distributed in some Ethiopian highland lakes and rivers (Golubtsov, and Mina, 2003) [11].

The study of food and feeding habits of freshwater fish species is a subject of continuous research. This is because it makes up a basis for the development of a successful management program on fish capture and culture (Shalloof and Khalifa, 2009) [22]. Moreover, studies on natural feeding of fish enable to identify the trophic relationships present in aquatic ecosystems, identifying feeding composition, structure and stability of food webs in the ecosystem (Adeyemi, 2009; Otieno *et al.*, 2014) [1, 20]. The information is also vital for management of the fish in the controlled environment and for formulation of the appropriate dietary given for the fish in aquaculture (Adeyemi, 2009) [1]. Therefore, understanding of its food and feeding behavior is a key factor to its successful culture in a controlled environment (Shalloof and Khalifa, 2009) [22].

Nile tilapia has a versatile feeding behavior, characterized by generalist and opportunistic omnivorous feeding behavior (Canonico *et al.*, 2005) [8]. Its diet composition may vary within a wide range of seasonal and spatial condition of the environments (Houlihan *et al.*, 2001) [12]. The food composition may also vary depending on size of the fish, maturity, environmental condition and habitat types (Kamal *et al.*, 2010) [13]. Various authors have studied the food and feeding habits of Nile tilapia in Ethiopian water bodies (Engdaw *et al.*, 2013; Negassa and Prabu, 2008; Tadesse, 1999; Tefera, 1993; Teferi *et al.*, 2000; Temesgen, 2017;

Wakjira, 2013 and 16; Teame *et al.*, 2016) [10, 17, 23- 27, 30-31]. All of them reported that Nile tilapia feed on different types of food based on the environment in which they live. However, there is no compiled information on the food and feeding habit of Nile tilapia in these different water bodies, which give the general insight on feeding biology of the fish in the country. Therefore, this review paper is aimed to summarize the food and feeding habits of Nile tilapia in Ethiopian water bodies.

2. Materials and Methods

Data sources were collected from June 2017 through November 2017. The different literature sources were used for this review including journal articles, books and book chapters, workshop proceedings, FAO reports, bulletins, legal documents and unpublished reports including PhD dissertations. The documents were collected from Addis Ababa University library, Hawassa University library, Ethiopian Ministry of Livestock and fishery, from different fishery research centers, from the individual researchers and Internet.

3. Food and feeding habits of Nile tilapia in Ethiopian water bodies

3.1. Diet composition of the Nile tilapia in the Ethiopian water bodies

Many authors have reported that Nile tilapia feeds on a variety of food items including phytoplankton, zooplankton, insects, detritus, macrophytes, fish parts and nematodes (Engdaw *et al.*, 2013; Negassa and Prabu, 2008; Tadesse, 1999; Tefera, 1993; Teferi *et al.*, 2000; Temesgen, 2017; Wakjira, 2013; Teame *et al.*, 2016) [10, 17, 23- 27, 30-31]. However, in terms of prey importance, the foods of plant origin (mainly phytoplankton) are the most consumed food types by the fish in all of the water bodies. For instance, the studies carried out in some rift valley lakes (e.g. Lake Hawassa (Tadesse, 1999) [23], Lake Chamo (Teferi *et al*., 2000) [26]., Lake Ziway (Negassa and Prabu, 2008) [17], Lake Langeno (Temesgen, 2017) [27] and Koka Reservoir (Engdaw *et al*., 2013) [10], some high land lakes (e.g. Lake Hayq (Worie and Getahun, 2015) [33], in lower Omo basin (e.g. Gilgel Gibe Reservoir (Wakjira, 2013) [30] and River Omo (Wakjira, 2016) [31] and Tekeze basin (e.g. in Tekeze Reservoir (Teame *et al.*, 2016) [24] indicated that phytoplankton is the most consumed food prey by Nile tilapia. In Lake Hashenge, however, zooplankton is the most widely consumed food type (occurred in about 60% of stomachs studies) by Nile tilapia, and this is an exceptional (Teame *et al.*, 2016) [24]. In addition to phytoplankton, the highest contribution of detritus was also reported in some rift valley lakes (e.g. Koka Reservoir (Engedaw *et al.*, 2013) [10] and Lake Langano (Temesgen, 2017) [27], and in other lakes like Lake Hashange (Teame *et al.*, 2016) [24], Gilgel Gibe Reservoir (Wakjira, 2013) [30] and Tekeze Reservoir (Teame *et al.*, 2016) [24]. The occurrences of macrophytes were also found slightly high in the diet of Nile tilapia in some of the rift valley lakes (Engedaw *et al.*, 2013; Negassa and Prabu, 2008; Teferi *et al.*, 2000; Temesgen, 2017) [10, 17, 26-27].

However, the contribution of animal origin was very small as compared to the food of plant origin except in Lake Hashange (Teame *et al.*, 2016) [24]. The occurrence of zooplankton in the diet of Nile tilapia was slightly highest in some of the high land lakes (e.g. Lake Hayq (Worie and Getahun, 2015) [33] and Lake Hashange (Teame *et al.*, 2016) [24] followed by some rift valley lakes (e.g. Lake Ziway (Negassa and Prabu, 2008) [17], Lake Chamo (Teferi *et al.*, 2013) [26], Lake Langano (Temesgen, 2017) [27] and Tekeze basin (Teame *et al.*, 2016) [24]. However, the less contribution of macrophytes was reported in other water bodies. The contribution of insects was highest in some southern rift valley lakes (e.g Gilgel Gibe Reservoir (Wakjira, 2013) [30] and Lake Chamo (Teferi *et al.*, 2000) [26] and Lake Hashange of the high land lakes (Teame *et al.*, 2016) [24]. The studies indicated that contribution of other food items were generally very low throughout the water bodies (Fig. 1). This indicates the changing of food items composition in the diet of Nile tilapia based on the diet composition in the lakes, which may varies depending on environmental condition, season (water level) and habitat types of the lakes.

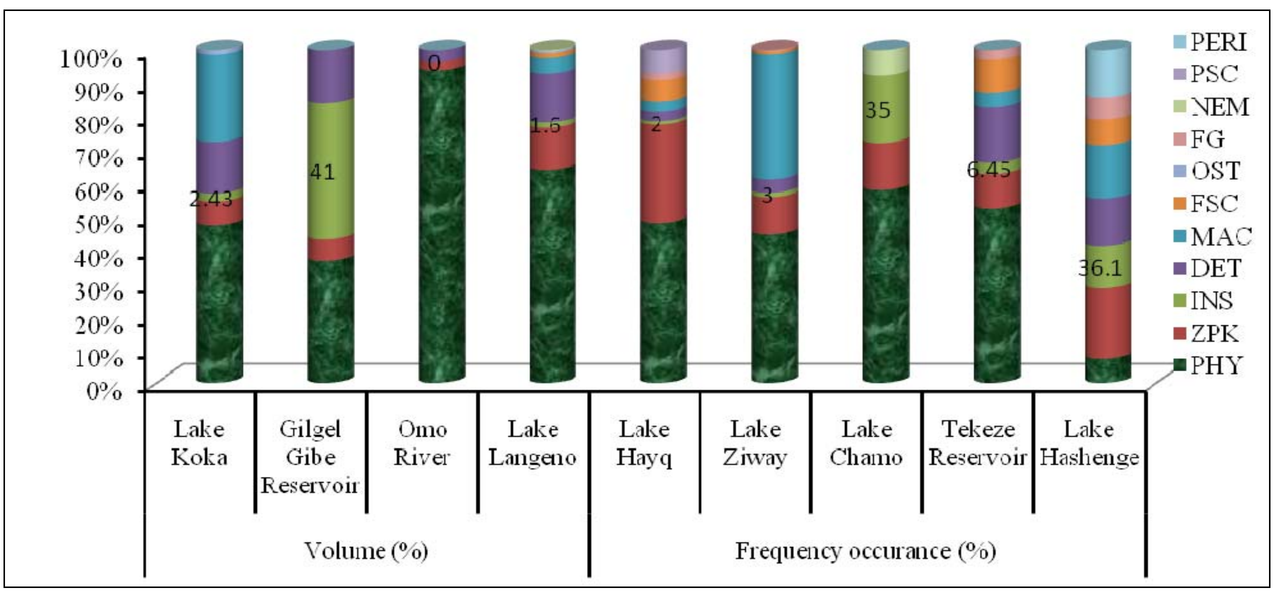

Fig 1: The mean volume (%) and frequency occurrence (%) of different food items in the diet of *O.niloticus* from some of the Ethiopian freshwater systems (MAC- Macrophytes, DET-Detritus, INS-Insects, PHY-Phytoplankton, OST-Ostracods, FSC-Fish scales, PSC-pisces, FG-Fish egg, NEM-Nematods, PERI-Periphyton and ZPK-Zooplankton).

3.2 Seasonal variation in the diet composition of Nile tilapia in Ethiopian water bodies

High water levels are designated as resource rich, while low water levels have poor resources in trophic dynamics mainly in lentic ecosystems (Balcombe *et al.,* 2014) [5]. The availability of food is dynamic throughout the year in tropics due to the seasonality of foods availability, and the feeding habit of fish also changes on the seasonal bases (Ballesteros *et al.,* 2009) [6]. In Ethiopian water bodies, many authors have also reported the seasonal variation of food types and their proportion in the diet of Nile tilapia. All of the studies indicated that phytoplankton is the most important food items consumed in dry season. For instance, the study made in Lake Koka showed that about 66.1% of the total volume of food items identified in the diet of Nile tilapia was phytoplankton followed by detritus 14.7% (Engedaw *et al.,* 2013) [10]. Similar findings were also reported in Lake Langeno (Temesgen, 2017) [27], Lake Hayq (Worie and Getahun, 2015) [33], Lake Ziway (Negassa and Prabu, 2008) [17], Lake Chamo (Teferi *et al.,* 2000) [26] and Omo River (Wakjira, 2016) [31]. The low proportion of phytoplankton during the wet season is associated with the high flooding from the catchment area, which can cause fluctuation in water level and increase turbidity (Njiru *et al.,* 2004) [18]. Turbidity of water decreases the penetration of sunlight and affects the growth and abundance of phytoplankton (Paaijmans *et al.,* 2008) [21]. Blue green algae like *microcystis* and diatoms are the most dominant phytoplankton in the diet of Nile tilapia reported during the dry season in most of the rift valley lakes, such as Lake Langeno (Temesgen, 2017) [27], Lake Koka (Engedaw *et al*., 2013) [10] and Lake Chamo (Teferi *et al.,* 2000) [26], and Lake Hayq (Worie and Getahun, 2015) [33] of the Ethiopian high land. According to Wisconsin Department of Natural Resource (2004) [32], warm temperature and lakes, ponds, and slow-moving streams enriched with nutrients like phosphorus or nitrogen are the most preferred habit for growth. However, in Gilgel Gibe I Reservoir, phytoplankton is the most important food items during wet season (Wakjira, 2013) [30]. Many studies have indicated that the feeding habit of the tropical fishes is dependent on the resource accessibility in the environment, which determines the choices and feeding preferences fish based on their trophic niches/or foraging areas (Ahrens *et al.* 2012; da Silva *et al.*, 2014) [2, 9].

In wet season, however, the high contribution of both plant origin (macrophytes and detritus) and animal origin (zooplankton and aquatic insects) were reported in most of the water bodies (Engedaw *et al.,* 2013; Negassa and Prabu, 2008; Tadesse, 1999; Teame *et al*., 2016; Teferi *et al*., 2000; Tefera, 1993; Teferi *et al.,* 2000; Temesgen, 2017; Wakjira, 2013; Worie and Getahun, 2015) [10, 17, 23-27, 30, 33].The high abundance of macrophytes and insects in the diet of Nile tilapia in wet season is associated with rainfall season of Ethiopia. Fish movements to shallow parts of the lake for reproduction could explain the increase of ingested macrophytes in the wet season. They stay there for a long period by feeding on macrophytes and vegetation in the wet season (Tefera, 1993) [25]. The high dietary proportion of detritus in the diet of the fish in wet season might also have emerged from plant materials flooding in during the rainy season (Worie and Getahun, 2015) [33]. The highest proportion of zooplankton during the wet season may also associate with the period of low water temperature and flooding time. Low water temperature is a prerequisite condition to the hatching of zooplankton in natural water (Mergeay *et al.,* 2006) [14]. In addition, the seasonal flooding can contribute to high zooplankton population in the water through bringing nutrients from the environment, and help in mixing autochthonous nutrients amongst the different strata of lake, which trigger the increasing of phytoplankton production and consequently zooplankton productivity (Okogwu, 2010) [19].

3.3 Diet composition in relation to fish size in Ethiopian water bodies

According to Otieno *et al.* (2014) [20], fish mainly feed on food items that can fit into their mouth, and what their stomach can digest. As fish grow, the stomach becomes longer, and their digestive system becomes more developed. However, the feeding rate relative to body weight decreases, whereas the absolute rate of food consumed increases (Wakil *et al.,* 2014) [29]. In most of the Ethiopian water bodies, the size based feeding study of Nile tilapia showed the highly dominance animal origin foods in the diet of fish with <11.5 cm TL. For instance, zooplankton (37.5%), insect (35%) and nematodes (13.5%) were the most frequently consumed food items by <11.5 cm TL in Lake Chamo (Teferi *et al*., 2000) [26]. Similarly, insects (30%) and zooplankton (25%) were the highly consumed food preys in Lake Koka by fish with <10 cm TL (Engedaw *et al.*, 2013) [10]. In Lake Langano, however, phytoplankton, zooplankton and insects were the mostly consumed types of food preys, which is different from the other waters (Temesgen, 2017) [27]. Generally, majority of the studies indicated that juvenile of *O. niloticus* are generally omnivorous, but mainly feed on zooplankton and insect larvae and some phytoplankton, of which diatoms is the major dietary component (Engdaw *et al.,* 2013; Temesgen, 2017; Worie and Getahun, 2015) [10, 27, 33]. This is because juvenile fish need high protein intake to support high growth rate and metabolism (Benavides *et al.*, 1994) [7]. Additionally, having a small stomach volume that cannot support big macrophytes, and detritus loads can be another reason for juveniles to feed on larval insects and zooplankton (Engdaw *et al.,* 2013) [10]. For the larger fish groups (>15 TL), however, the plant origin food types (phytoplankton, detritus and macrophytes) were the highly preferred food types. According to Benavides *et al.* (1994) [7], Nile tilapia change their feeding behavior from primarily omnivorous to herbivorous with the high-energy demands as they grow in size. The growing demand of energy cannot be met by feeding only on zooplankton and benthic invertebrates. This enables them to shift their feeding behavior from eating only zooplankton and benthic invertebrates to the generalist behavior. In addition, the bigger fish are more capable of digesting cell wall material, and therefore can be less selective in their feeding pattern (Tadesse, 1999) [23]. The shift in feeding behavior shows a low degree of intraspecific competition for particular food among different length groups (Ayoade *et al.*, 2008) [4].

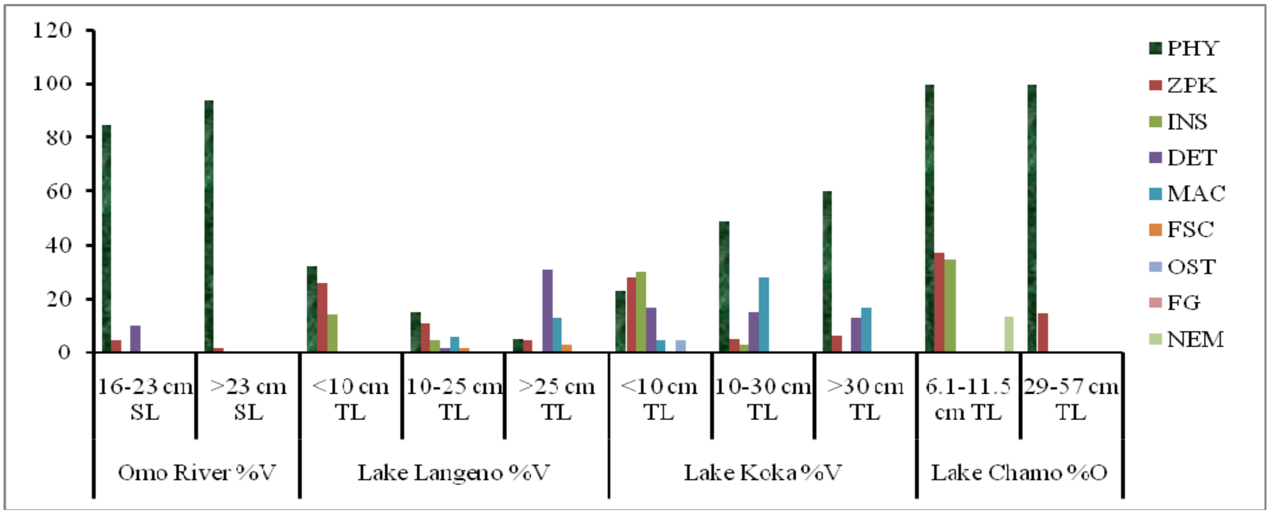

Fig 2: The mean volume (%V) and frequency occurrence (%O) of different food items in relation to fish size of *O.niloticus* from some of the Ethiopian freshwater systems (MAC- Macrophytes, DET-Detritus, INS-Insects, PHY-Phytoplankton, OST-Ostracods, FSC-Fish scales, FG-Fish egg, NEM-Nematods, and ZPK-Zooplankton).

4. Conclusion

Oreochromis niloticus found to be omnivorous in its feeding habits in all water bodies. The food items of plant origin dominate the stomach contents of the fish except in Gilgel Gibe Reservoir and Lake Ashange, which typically associated with less protein content than animal origin food items. The seasonal and habitat type based variation was a common phenomenon observed among the water bodies, which may depend on the availability of the food in the water. The size related variation in diet composition was also observed in all of the water bodies. The size-related shifts in food item preferences of Nile tilapia seem to depend upon physiological requirements, whereas the seasonal changes in dietary pattern might rather reflect the opportunistic feeding behavior of the species. Therefore, further study in the dietary aspect of the fish feeding habit, and works on the further improvement and optimization protein rich feed is very important at aquaculture level.

5. Conflict of interest

The author(s) declare(s) that there is no conflict of interests regarding the publication of this article." Otherwise, they should mention any conflict of interest in this section of the manuscript.

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