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Research Article

Dietary shifts in Juvenile and Adult Nile Tilapia, Oreochromis Niloticus (L.) (Pisces: Cichlidae) in Lake Ziway, Ethiopia

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ABSTRACT

Oreochromis niloticus (Nile tilapia) is an important fish in the ecology of tropical waters as well as aquatic systems in other subtropical regions. It is the most commercially important and preferred fish species in Ethiopia. It is also a candidate fish for aquaculture. In recent years, the fish community structure and ecosystem dynamics of the Lake Ziway have changed, but no studies have been carried out to assess whether the fishes have altered their diets in the lake. Indeed the food of Nile tilapia with respect to size was conducted from April to August 2017 in Lake Ziway, Ethiopia.A total of 365 Nile tilapia specimens (170 adults and 195 juveniles) were collected ranging from 2.5 to 30 cm TL and 0.5 to 459.7 g TW. Guts of 165 (85%) juveniles and 115 (73.5%) adults' contained food items. Specimens that contained food items in their stomachs were analyzed using frequency of occurrence, volumetric methods and Schoener's index. Nile tilapia originally known to be phytoplanktivorous has shifted to omnivorous feeding mainly on macrophytes. Volumetrically, the major diets of juveniles were zooplankton (33.79%), phytoplankton (25.44%), insect (18.69%) and detritus (14.02%) while the diet of adults were mainly macrophytes (36.2%) followed by phytoplankton (34.36%) and detritus (18.41%). Adult Nile tilapia which was a phytoplanktivorous has now shifted to macrophytes even though phytoplankton is the second dominant food item while juvenile mainly depends on zooplankton and insect larvae. Ontogenetic diet shift was observed in the present study demonstrating juveniles mainly feeding on animal based food items whereas adults depend on plant origin.

Keywords: Diet Composition, dietary shift, Nile tilapia, Temporal variation

INTRODUCTION

Nile tilapia is native to Central and North Africa and has been introduced to many parts of Asia, Europe, North America and South America due to its suitability to aquaculture [1]. It is also an important fish in the ecology of tropical waters as well as aquatic systems in other subtropical regions [2]. The fish feeds mainly on algae and other plant materials as well as detritus making it a link between lower and upper trophic levels in the aquatic food webs. In Ethiopia,Nile tilapiaiswidely distributed in lakes, rivers, reservoirs and swamps, and contributes about 60% of total landings of fish [3,4], but currently reduced to 49% [5], and in Lake Ziway particularly its contribution has declined from 89.3% in 1994 to 27% in 2014 [6]. As a result of declining contribution of Nile tilapia in the lake, around 70% of the annual catch of the lake is covered by exotic fish species (Cyprinus carpio, Carassius carassiusand Clarias gariepinus) ([6].

The dramatic decline of Nile tilapia in the lake could be related to food availability in the lake which is located in the vicinity of a growing town, where human population pressure has been increasing, agriculture and floriculture is expanding in the drainage basin. Accordingly, land degradation, soil erosion and nutrient runoff have increased. As a result, the turbidity of the

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lake is very highand primary productivity is light rather than nutrient limited [7, 6]. Hence, phytoplankton biomass is declining, which is a diet of Nile tilapia. It has also been reported that the presence of high load of suspended sediments had made it difficult for filter feeding behavior of tilapia [8]. In Ethiopian water bodies, adult Nile tilapia was observed feeding primarily on phytoplankton whereas juveniles are generally omnivorous feeding on zooplankton and insect larvae [9,10,11] and phytoplankton of which diatom was the major dietary component [9, 12].

In recent years, the fish community structure and ecosystem dynamics of the lake have changed, but no studies have been carried out to assess whether the fishes have altered their diets in the lake. Recently [8] reported that 64% of adult Nile tilapia diet originated from macrophytes in Lake Ziway using stable isotope analysis, which however, has not been corroborated with established conventional method. Therefore, updated information on the feeding habits of Nile tilapia is currently mandatory as the fish is the most commercially important and preferred fish species in Ethiopia. It is also a candidate for aquaculture. The aim of this study was to determine whether Nile tilapia has changed its feeding habits with ecosystem and fish community structure changes in the lake. The study also assessed ontogenetic dietary shift of Nile tilapia andtemporal variation in its diet in Lake Ziway. The information would be useful to create a trophic model that can be used in fisheries management and designing conservation strategies for sustainable utilization of the fishery resources of the lake.

MATERIALS AND METHODS

Study area description

Lake Ziway (70 52' to 80 8' N latitude and 70 52' to 380 56' E longitude) is one of the freshwater Rift Valley Lakes of Ethiopia [13] and is situated at an altitude of 1636 meters above sea level with a surface area of 434 km2 [14]. It is found at about 160 km south of Addis Ababa. Two main rivers, Meki from the north-west and Katar from the east are flowing into the lake and it has an outflow through Bulbula River, draining into Lake Abijata (Fig.1). The lake supports seven indigenous and six introduced fish species [6] of these the native Oreochromis niloticus and the exotic Cyprinus carpio, Carassius carassius, and Clarias gariepinus were the most important commercial fish species in the lake.

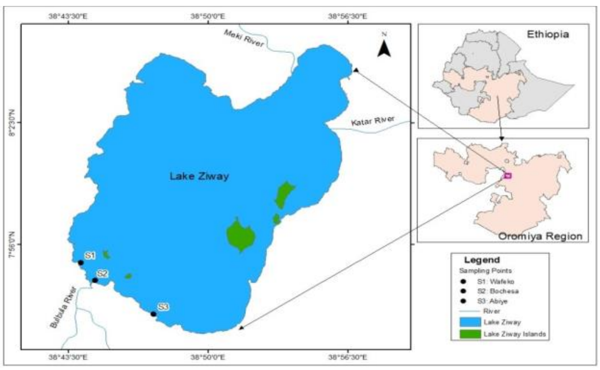

Figure 1: Map of Ethiopia and Lake Ziway with sampling sites

Fish collection and measurement

Adult fish samples were obtained from fishermen. The commercial gillnets of the fishermen consist of different mesh sizes (6cm, 8cm, 10cm and 12cm stretched mesh sizes). In order to obtain juveniles, a beach seine (3 cm mesh size) was used in the shallow part of the lake. Fish samples were identified using keys developed by [15] and [16].Total length (TL) and total weight (TW) of all specimens were measured using a measuring board and a sensitive balance to the nearest value of 0.01 cm and 0.01g, respectively. Each fish was dissected and the sex and maturity stage of each sample was determined by visual examination of gonads using 5 point maturity scale [17]. Stomach containing food were transferred to a labeled plastic bag containing 4% formaldehyde solution and then brought to the fishery laboratory of Addis Ababa University for analysis.

Gut content analysis

In the laboratory, the content of each stomach of Nile tilapia was transferred into a petri-dish to identify food items either visually and/or microscopically. Smaller food items were examined under a dissecting microscope (LEICA MS5, LEICA DME, magnification 40X) and identified to the lowest possible taxa using descriptions and illustrations in the literature [18, 19]. Then, the relative importance of each food item to the diet of the fish was estimated using frequency of occurrence and volumetric methods.

Frequency of Occurrence

A frequency of occurrence was defined as stomach samples contain one or more of a given food item was expressed as a percentage of all non-empty stomachs examined [20 21].

$$\%\mathbf{Fi} = \frac{The\ numberof\ stomachs\ in\ which\ a\ given\ food\ item\ is\ found}{Number\ of\ stomachs\ containing\ food} * 100$$

Where %Fi is the frequency of occurrence of given food i

Volumetric Analysis

Food items that are found in the guts were grouped into different taxonomic categories and the water displaced by a large group of fooditems was measured in a partially filled graduated cylinder [20]. The volume of the water displaced by each category of food items was expressed as a percentage of the total volume of the gut contents [21]. In case of microscopic food items, the estimated average volume of an individual organism was multiplied by the total number of organisms counted in the gut samples.

$$\%\mathbf{Vi} = \frac{Volume\ of\ one\ food\ item\ found\ in\ all\ specimens}{The\ volume\ of\ all\ food\ items\ in\ all\ specimens} * 100$$

Where %Vi is the percentage of food item i

Temporal diet variation of common carp and Nile tilapia

The monthly difference in the feeding habit was studied by plotting the relative importance of major food items against sampling months.

Diet Overlap analysis

Dietary overlap of different size-classes and between the two species was calculated using, Schoener Diet Overlap Index (SDOI) [22, 23] calculated as follows:

$$a = 1 - 0.5 * \left(\sum_{i=1}^{n} |pxi - pyi|\right)$$

Where α is percentage overlap, SDOI, between length classes x and y, pxi and pyi are proportions of food category (type) i used by x and y. Values of α range from 0 (no food overlap) to 1 (all food items in equal proportions) with values greater than 0.6 considered as biologically important [23, 24].

RESULTS

Diet composition of juvenile and adult Nile tilapia

Visual and microscopic examination of gut contents of Nile tilapia showed diverse items of insects, phytoplankton, zooplankton, ostracods, nematodes and unidentified fragments of animal parts, fish scale, macrophytes and detritus of these items, some insect larvae (Plecoptera and Hemiptera), some zooplankton groups like Keratella sp., Ceriodaphnia cornuta and Alona sp., and ostracods which are found in gut of juvenile Nile tilapia were not found in the gut of adult Nile tilapia. Similarly, some phytoplankton groups like Anabaenopsis sp., Coelastrum sp., and Nitzschia sp. were found in guts of adult Nile tilapia but not in the gut of juveniles.

The relative contribution of food items in the diet of juvenile and adult Nile tilapia

Frequency and volumetric contribution of different food items in juveniles and adults of Nile tilapia in Lake Ziway is given in Table 1. In juveniles of < 10 cm TL, phytoplankton constituted the largest component of the diet occurring in 85.29% followed by zooplankton (83.53%) and detritus (72.65%). Insects contributed moderately and occurred in 66.80% of the stomachs examined. Volumetrically, the major portion was zooplankton (33.79%) followed by phytoplankton (25.44%), insect (18.69%) and detritus (14.02%) (Table 1). Correspondingly, zooplankton, phytoplankton, insect and detritus were the most important food items of juvenile Nile tilapia in Lake Ziway. Other than the four major food items, macrophytes, nematodes, ostracods and unidentified animals made up a relatively lower portion of the diet of juvenile Nile tilapia. In adults (11-30 cm TL), phytoplankton constituted the largest component of the diet occurring in 89% followed by detritus (82%) and macrophytes (79%).Volumetrically, macrophytes were dominant making up 36.2% followed by phytoplankton (34.36%) and detritus (18.55%) (Table 1). Accordingly, macrophytes, phytoplankton and detritus were the most important food items of adult Nile tilapia in Lake Ziway. On the other hand food items such as nematodes, ostracods and unidentified animals made up a minor portion of the diet of adult Nile tilapia like that of juvenile Nile tilapia with relatively higher in juvenile Nile tilapia (Table 1). There was a high variation in the diet of juvenile and adult Nile tilapia (α=0.52) indicating the presence of ontogenetic dietary shift.

Food items	**Juvenile**		**Adult**	
	Frequency of occurrence (%)	**Volumetric contribution (%)**	**Frequency of occurrence (%)**	**Volumetric contribution (%)**
Phytoplankton	85.29	25.44	89	34.36
Blue green algae	55.1	5.79	81	13.76
Green algae	48.35	3.45	62	9.85
Diatoms	72.75	15.39	75	10.01
Euglena	4.8	0.81	7	0.74
Zooplankton	83.53	33.79	58	6.52
Rotifers	60.78	3.28	45	1.42
Copepodes	79.41	22.29	42	3.24
Cladocerans	54.9	8.22	31	1.86
Insect	66.8	18.69	24	2.28
Diptera	61.67	12. 68	22	1.63
Ephemeroptera	34.91	1.68	10	0.28
Hemiptera	20.59	1.08	-	--
Plecoptera	16.67	1.09	-	-
Coleoptera	38.63	2.24	13	0.37
Ostracods	9.8	1.79	-	--
Nematodes	19.61	3.64	16	1.32
unidentified animal fragments	11.76	1.57	7	0.77
Macrophytes	32.35	1.06	79	36.2

Detritus	72.65	14.02	82	18.55

Table 1: Frequency of occurrence and volumetric contributions of different food items consumed by (n=365) Nile tilapia from Lake Ziway

Temporal variation in the diet of juvenile and adults of Nile tilapia

The result clearly shows temporal variation in the diet of juvenile and adult Nile tilapia. The contribution of phytoplankton was high from April to May occurring in 91.67% to 92.86% of the total stomach and constituted 49% to 51% of the total volume of food items and low from June to August occurring from 85.71% to 54.28% and constituting 32.51% to 12.22% of the total volume of food items (Fig. 3). Conversely, the volumetric contribution of detritus was high in August (30%) and low in May (13 %) (Fig. 2). The contribution of macrophytes was low in May occurring in 61.16% of the total stomach and constituting 23.4% of total volume of the stomach and high in August occurring in 89% of the total stomachs and constituting 52.81% of the total volume of the stomachs (Fig. 2). Similar to adult Nile tilapia, juvenile Nile tilapia mainly feed on phytoplankton from April to May occurring from 84.57% to 88% of the stomach and comprising 35.72% to 37.04% of the total volume of food items, while decreased from June to August occurring from 63.16% to 41% and comprising 23.94% to11.97% of the total volume of food items, respectively (Fig. 2). The contribution of zooplankton was comparable among months and their volumetric contribution ranged from 33% in May to 38.43% in July (Fig.2). Similarly the contribution of insect was comparable among months in which their volumetric contribution ranged from 16.96% in August to 20.27% in June.

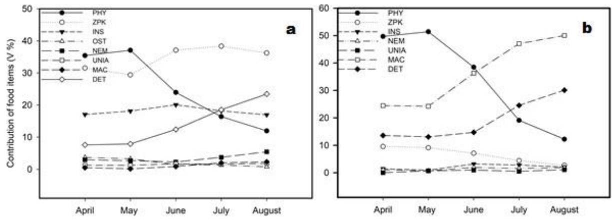

Figure 2: Monthly variation in the diet of Nile tilapia from Lake Ziway from April-August 2017 (a) Juvenile Nile tilapia and (b) Adult Nile tilapia.Abbreviations: PHY=phytoplankton, ZPK=zooplankton, INS=insects, OST=ostracoda, NEM=nematode, UNIA= unidentified animal, MAC=macrophytes and DET=detritus).

DISCUSSION

Feeding habit of juvenile and adult Nile tilapia

Nile tilapia fed on phytoplankton, macrophytes, detritus, zooplankton, insects, and nematodes. Among these food items, macrophytes followed by phytoplankton and detritus were the dominant diets of adult Nile tilapia in Lake Ziway. Earlier studies carried out in some rift valley lakes (e.g. Lake Ziway by [1, 9], Koka Reservoir by [11] have indicated that phytoplankton was the most consumed food item by Nile tilapia. The dominance of macrophytes in the present diet of Nile tilapia over phytoplankton could be due to declining phytoplankton biomass in Lake Ziway [7] and the presence of high load of suspended sediments that is difficult for filter feeding behavior of tilapia [8]. The predominance of macrophytes to a diet of adult Nile tilapia in the present study is also in agreement with the report by [8] that indicated the high contribution of macrophytes (64%) in the diet of Nile tilapia in the same lake. Similarly, [25] have also reported the high contribution of macrophytes (54%) in the diet of Nile tilapia in South Lake, China. In addition to phytoplankton and macrophytes, detritus was also consumed in large quantities. [26] and [27] have reported the importance of detritus in the diet of Nile tilapia in Lake Langeno and Lake Chamo (Ethiopia), respectively. [28] has also reported the presence of large quantities of detritus in the diet of Nile tilapia in Lake Valencia (Venezuela). Several authors have also provided similar interpretations about the importance of detritus in the diet of tilapia in different parts of Africa [11, 29, and 30]. However, the contribution of animal origin (zooplankton, insect and nematodes) was low to the diet of adult Nile tilapia of Lake Ziway. This is alsoin line with the study by other authors [11, 27]. The reason for taking less zooplankton during adult life might be that the fish changes its mode of feeding by gulping the water within its area. The zooplankton may detect feeding current and swim away to avoid being swallowed by the fish [11]. On the other hand, the dominance of plant-based food items (particularly macrophytes) and detritus over animal origin in the diet of adult Nile tilapia could be attributed to wider mouth gapes and their developed digestive system in terms of having more developed digestive enzymes, coupled with longer and larger gut length. This makes it possible for the fish to digest more complex food items like plant materials which cannot be digested at younger ages. As a result, their enzymes can break the cell walls of plant materials. Unlike the adults, juvenile Nile tilapia mainly fed on zooplankton followed by phytoplankton and insects. This is also in agreement with other reports ([10] in Lake Hawassa; [9] in Lake Ziway; [11] in Lake Koka). In Lake Koka Nile tilapia of <10 cm TL mainly fed on zooplankton (25%) and insects (30%) and this trend declined sharply as the size of fish increased above 10 cm TL [11]. Zooplankton were the most important food items for fish less than 5 cm TL and little importance for larger than 10 cm TL of Nile tilapia in Lake Victoria [31]. Similarly, zooplankton (46%) were the most important food items for fish less than 10 cm TL and of little importance for fishes larger than 10 cm TL in Lake Tinishu Abaya (Ethiopia) [32]. The result of the present study is also in agreement with [10]; [9] and [27] who reported the significant contribution of zooplankton to smaller sized Nile tilapia. The possible reason for juveniles feeding on zooplanktons and larval stages of insects over plant materials (macrophytes and phytoplankton) and detritus might be due to the small volume of the stomach that may not support big macrophytes and detritus [11]. Furthermore, [33] hypothesized that since juvenile fish have higher mass protein demand due to their higher specific growth rate and greater mass specific metabolism, they may not satisfy this demand by consuming a plant-based diet. Thus, younger fish tend to feed more on animal origin including zooplankton and insect larvae and shift to plant based foods as they grow. In addition to zooplankton and insect larvae, juvenile Nile tilapia mainly feeds on phytoplankton particularly diatoms. This is also in agreement with [9]. The high contribution of diatom in the diet of juvenile Nile tilapia might be associated with small size of diatom and its high nutrition value when compared with filamentous algae. The type and size of food items consumed changes with age and size of the fish. This is mainly because fish can only feed on food items that can fit into their mouth and what their gut can digest [34]. The importance of phytoplankton, macrophytes and detritus was higher in adults than in juveniles whereas the importance of zooplankton, insects, and other animal origin food was higher in juvenile than in adults. This result indicates that there was ontogenetic dietary shift in the diet of Nile tilapia. Schoener Index value also indicate that there was a high variation in the diet of juvenile and adult Nile tilapia (α=0.52).Similar results also reported by [32] who reported that there was no significant dietary overlap between juvenile and adult Nile tilapia in Lake Tinishu Abaya, Ethiopia. Furthermore, [35] reported that ontogenetic diet shift has been shown to occur during the life history of many fish species as prey size is generally positively correlated with fish size.

Temporal variations in the diet of juvenile and adult Nile tilapia

The temporal changes of biotic and abiotic factors alter the structure of the food web along the year and as a consequence, the fish often shows temporal and seasonal diet variation. In the present study, the proportion of phytoplankton was higher from April to May and low from July to August (Fig.2). Among the phytoplankton, blue green algae were dominant in April and May, and diatoms were also dominant from June to August. This is quite similar with the findings of other investigators in the Ethiopian rift valley lakes [9, 11, and 27] who reported that blue green algae are dominant in dry months and diatoms are dominant in wet months. According to [11] the contribution of phytoplankton to the diet of Nile tilapia was high (66.1%) in dry month (May) and very low (3.51%) in wet month (August). On the contrary, the contribution of macrophytes was high from July to August and low from April to May. The differences in composition and the varying relative contribution of food items may be due to the difference in micro habitat occupied by the fish. During dry months fish may move to the pelagic region of the lake and feed mainly on suspended phytoplankton because, phytoplankton production may be high due to increased light penetration into the photic zone of the lake [11]. That is why the contribution of phytoplankton was higher in dry months than in wet months as primary production of Lake Ziway is light rather than nutrient limited [7, 8].On the other hand, during wet months high flooding from the catchment area may cause fluctuations in water level and increase the turbidity of the lake. This decreases light penetration in the lake, thereby affecting the growth and abundance of phytoplankton in the water [36]. Since the biomass of phytoplankton in the lake is low in wet months, Nile tilapia has to rely on any plant material available in the lake that is why macrophytes and detritus constitute the bulk of its diet during July and August. In addition, during wet months fish moves to shallow parts of the lake for reproduction and stays for longer period of time by feeding macrophytes. In addition to macrophytes, the contribution of detritus to the diet of Nile tilapia was high in July and August. The high contribution of detritus in these wet months could be associated with plant materials coming with runoff during the wet months ([26, 37]. The contribution of zooplankton to the diet of adult Nile tilapia was low in July and August, and relatively high in April and May and moderate in June (Fig. 2). This is in line with [11] who reported that contribution of zooplankton was higher in a dry month (May) (9.7%) than a wet month (August) (1.2%) in Lake Koka. In case of juveniles of Nile tilapia, the contribution of zooplanktonwas high in all monthswith peak in July and low in May (Fig. 2). The highest proportion of zooplankton during July and August months might be associated with the low availability of phytoplankton which is the second important food item for juvenile Nile tilapia. In contrast, the contribution of phytoplankton was high in May and low in August (Fig. 2). The reverse is true for the contribution of detritus to the diet of juvenile Nile tilapia in Lake Ziway (Fig. 2). A similar result was also reported by [11] from Lake Koka. However, the contribution of insects to the diet of juvenile Nile tilapia was comparable among months with relatively higher in June.

CONCLUSION

Nile tilapia has a diverse feeding habit that includes macrophytes, phytoplankton, zooplankton, fish scale, insects and detritus. Macrophytes and phytoplankton was the dominant food item consumed by the adult Nile tilapia while juvenile mainly depends on zooplankton and insect larvae. Ontogenetic diet shift was observed in the present study demonstrating juveniles mainly feeding on animal based food items whereas adults depend on plant origin. However, diet temporal variation was observed in both juveniles and adults, which are omnivores feeding on different levels of plant and animal origin food items.

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