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Diet composition, ontogenetic dietary shifts and morphometric relationships of the Nile barb *Barbus bynni* (Forsskål, 1775) (Pisces: Cyprinidae) in Lake Abaya, Ethiopia

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Food and feeding habits of *Barbus bynni* (Forsskål, 1775) were studied in Lake Abaya, Ethiopia, from January to February, 2010 (dry season) and May to June, 2010 (wet season). From a total of 292 fish samples, 251 (86.0%) contained food in their guts. Macrophytes, insects and detritus were the dominant food categories both during the dry and wet seasons. Macrophytes and detritus occurred in 78.1 and 73.3% of the guts, and constituted 30.4 and 29.3% of the total food volume, respectively while insects occurred in 72.5% of the guts and accounted for 29.2% of the total volume. Zooplankton occurred in 37.5% of the guts but they constituted only 4.6% of the total volume of food categories. No seasonality in diet was observed, however, there was an ontogenetic change in diet. In juveniles, the contribution of food of animal origin was relatively high, whereas in adults the contribution of plant materials was dominating. The relationships between total length (TL) and total weight (TW) of males, females and both sexes combined were curvilinear and statistically significant ($P < 0.001$). The relationships between TL and fork length (FL), TL and standard length (SL) and FL and SL were all linear and statistically significant ($P < 0.001$). The growth pattern of *B. bynni* in Lake Abaya was allometric because the slope of the relationship (b) was 3.25, which is a value considerably higher than 3.

Key words: *Barbus bynni*, diet composition, feeding habits, Lake Abaya, morphometric relationships.

INTRODUCTION

The Nile barb *Barbus bynni* (Forsskål, 1775) is a benthopelagic freshwater fish widely distributed in the Nile system and in lakes that were once connected to

the Nile (Golubtsov and Krysanov, 1993; Bailey, 1994). In Ethiopia, the species is widely distributed in the Southern Rift Valley Lakes, Abaya and Chamo, the

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Figure 1. Map of Africa with horn of Africa region highlighted (a), map of Ethiopia with the southern rift valley lakes area indicated (b), maps of Lakes Abaya and Chamo with the sampling area in Lake Abaya shown (c).

Omo River and the rivers that drain into the Nile system (Golubtsov et al., 1995; Getahun, 2007; Golubtsov and Habteselassie, 2010).

African barbs belong to the genus *Barbus* and are divided into small and large barbs. The division is supported by cytogenetics, the smaller barbs having 50 chromosomes while the large barbs have 150 (Berrebi and Valiushok, 1998). *B. bynni* belongs to the large *Barbus* group sensu (Banister, 1973).

Although *B. bynni* is commercially important in Lake Abaya, no study has been conducted on the biology and ecology of the species. No published information is available on the food and feeding habits and morphometric relationships of *B. bynni* in African water bodies in general and in Lake Abaya in particular.

The aim of this work was, therefore, 1) to investigate the food and feeding habits of *B. bynni* in Lake Abaya,

and 2) to provide basic information on morphometric relationships of this species in Lake Abaya.

MATERIALS AND METHODS

Study area

Lake Abaya (Latitude: 5°30' - 6°30' N and Longitude: 36°30' - 38°30'E) is the largest Ethiopian Rift Valley Lake located in the southern part of the Ethiopian Rift Valley, east of the Guge Mountains, at an elevation of 1,285 m (Figure 1). The Bilate River that rises from the southern slope of the Gurage Mountains is the major influent of the lake (Baxter, 2002). The town of Arbaminch lies on its southwestern shore. The lake has a maximum length of 60 km, width of 20 km, and a catchment area of 17,300 km² (Tudorancea et al., 1999). The surface area of the lake is 1,162 km², with a maximum depth of 13 m (Baxter, 2002).

There are a number of islands in this lake, the largest being Aruro;

others include Gidicho, Welege, Galmaka, and Alkal. The lake is reddish in color due to high load of suspended clay particles. Lake Abaya does not always have an outflow, but in some years, it overflows into Lake Chamo. Nech Sar National Park, known for its wild life and bird life surrounds the lake, which is also fished by local people. The ichthyo-fauna of Lake Abaya, and also that of the neighbouring Lake Chamo, is Soudanian species (Beadle, 1981). The fish species are more diverse than that of the other rift valley lakes of the country probably due to a previous inter-connection of Lakes Abaya, Chamo, Chew Bahir and Turkana with the Nile system (Beadle, 1981). There are 21 fish species found in Lakes Abaya and Chamo and the inflowing rivers (Golubtsov and Habteselassie, 2010). The commercially important species are *Oreochromis niloticus* (Linnaeus, 1758), *Labeo horie* (Heckel, 1847), *Bagrus docmak* (Forsskal, 1775), *Clarias gariepinus* (Burchell, 1802) and *Lates niloticus* (Linnaeus, 1758).

According to Tudorancea et al. (1999), the lake has a secchi disc depth of 19 cm and a pH of 8.7 with conductivity (K_{25}) of 800 $\mu\text{S}/\text{cm}$. The area in which the lake lies is mainly volcanic in origin while the waters of the lake are permanently turbid due to heavy colloidal suspension of ferric oxide and the high turbidity of the lake greatly reduces primary productivity and fish production (Schröder, 1984).

Fish sampling and measurements

Sampling was done four times, twice during the dry season (January and February) and twice during wet season (May and June). In the shallow littoral area, a beach seine (25 m long and 3 m wide with a mesh size of 0.6 cm) was used for sampling, while Nordic survey multi-mesh monofilament nylon gillnets (Appelberg et al., 1995) were used in the pelagic area of the lake (Figure 1). The multi-mesh gillnets consisted of twelve randomly distributed panels of the mesh sizes 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 25, 29, 35, 43, and 53 mm (bar mesh). Each panel was 2.5 m long, and hence the total length (TL) of each net was 30 m. The nets were 1.5 m deep with a total area of 45 m^2 . The depth of the water where the gillnets were set ranged between 3 to 5 m about 1.5 km inward from the littoral sampling station. They were set around 7.00 am and pulled around 3.00 pm. A total of 292 fish were collected. Fish were then removed from the gillnets shortly after landing. The TL, fork length (FL) and standard length (SL) were measured to the nearest mm, while total weight (TW) was measured to the nearest gram.

Food and feeding

Since *B. bynni* has no distinct stomach, contents of the entire gut were taken and preserved in 5% formalin immediately after morphometric measurements were taken. The gut contents were examined and prey items identified under a dissecting microscope (LEICA MS5, magnification 40x) and compound microscope (LEICA DME, magnification 100x), in the Biology Laboratory at Hawassa University. The relative importance of food items was determined using the following methods:

Frequency of occurrence

The number of gut samples containing one or more of a given food items was expressed as a percentage of all non-empty guts examined (Bagenal and Braum, 1978). The proportion of the population that feeds on certain food items was estimated by this method.

Volumetric analysis

Food items that were found in the guts were sorted into different food categories, and the water displaced by a group of items in each category was measured in a partially filled graduated cylinder (Bowen, 1983). The volume of water displaced by each category of food item was expressed as a percentage of the total volume of the gut contents (Bowen, 1983). The importance of different food categories was determined by categorizing the TL of the fish into four size classes (I: 10.0 to 19.9 cm, II: 20.0 to 29.9 cm, III: 30.0 to 39.9 cm and IV: 40.0 to 49.9 cm) and the total volume of food in each size class was determined. The volumetric contribution of each of food category was then expressed as a percentage of the total volume of food consumed in each size class.

Statistical analysis

Chi-square test was used to compare frequency of occurrences of the different food categories during the dry and wet seasons (Sokal and Rohlf, 1995). Similarly, the non-parametric Mann-Whitney's U test was used to compare the volume of the different food categories consumed during the dry and wet seasons since the data did not satisfy the assumption of equal variance to employ a parametric test.

Dietary overlap between different length-classes was calculated using Schoener Diet Overlap Index (SDOI) (Schoener, 1970; Wallace, 1981):

$$\alpha = 1 - 0.5 \left(\sum_{i=1}^n |px_i - py_i| \right) \quad (1)$$

Where α is percentage overlap, SDOI, between length classes x and y , px_i and py_i are proportions of food category (type) i used by x and y , and n is the total number of food categories. Overlap in the index is generally considered to be biologically significant when α value exceeds 0.60 (Mathur, 1977).

Morphometric relationships

Length-weight relationship was calculated using the following formula:

$$TW = aTL^b \quad (2)$$

Where TW is total weight (g), TL is total length (cm), and a and b are intercept and slope of the length-weight regression equation, respectively.

A linear relationship was used to determine the relationships between TL and FL, TL and SL and FL and SL.

RESULTS AND DISCUSSION

Diet composition

B. bynni ranging from 11.6 to 50.0 cm TL and 14.2 to 1,200 g TW were considered for food and feeding habit study. The longest female in the sample was 50 cm TL and 1,200 g TW, whereas the longest male fish was 35.8 cm TL and 359.2 g TW. The size frequency distribution of the fish during both dry and wet seasons is given in

Figure 2. Size frequency distribution of *B. bynni* during the dry (n = 89) and wet (n = 162) seasons in Lake Abaya.

Figure 2. Out of the total number of 292 examined fish, 41(14%) had empty guts. The food categories found in the guts of 251 individuals of *B. bynni* included macrophytes, detritus, insects, zooplankton, phytoplankton, ostracods, gastropods and nematodes (Table 1). Macrophytes, detritus and insects were the most important food categories of *B. bynni* in Lake Abaya. Zooplankton were also encountered relatively frequently, while the remaining food categories (ostracods, nematodes, gastropods and phytoplankton) occurred in few guts (Table 1).

Macrophytes occurred in 78.1% of the examined guts and volumetrically they accounted for 30.4% of the total food volume (Table 1). Detritus occurred in 73.3% of the guts and accounted for 29.2% of the total volume, while insects occurred in 72.5% of the guts and accounted for 29.1% of the total volume. The digestibility of plant food categories could be an important factor in their relatively higher volume, because food of plant origin may resist digestion while soft bodied invertebrates and zooplankton may be lost quickly due to digestive processes. Zooplankton occurred in relatively high number of guts (37.5%), but their volumetric contribution was small (4.6%). Nematodes, ostracods, gastropods and

phytoplankton occurred in 4.0 to 21.5% of the guts and collectively accounted for only 6.5% of the total food volume (Table 1). Among the three zooplankton groups identified in the guts of *B. bynni*, *Daphnia* sp. occurred in 19.9%, and accounted for 3.2% of the total volume, followed by *Ceriodaphnia* sp. and rotifers that occurred in 10 and 9.2%, and constituted 0.6 and 0.7% of the total food volume, respectively. Among the insects, Chironomidae larvae occurred in 43.0% of the guts and accounted for 11.3% of the total volume, followed by Ephemeroptera occurring in 22.3% and constituting 9.3% of the total volume (Table 1). Coleoptera and Plecoptera were also relatively important food items, occurring in 25.1 and 22.7% of the guts respectively and accounting for 3.5 and 3.3% of the total volume, respectively. The remaining insects were of minor importance, with occurrence in few guts, and with low contribution to the total gut content. Among the three phytoplankton categories identified, diatoms accounted for 1.1%, followed by blue green algae (0.7%), and green algae (0.4%) by volume.

Apparently, there are very few studies done concerning the food and feeding habits of *B. bynni*. Froese and Pauly(2010) have reported that three sub-species of *B. bynni*: *B. bynni bynni*, *Barbus bynni occidentalis* and *B.*

Table 1. Frequency of occurrence and volumetric contribution of food items consumed by *B. bynni* in Lake Abaya (n = 251).

Food item	Frequency of occurrence		Volumetric contribution	
	Frequency	Percent	Volume (ml)	Percent
Macrophytes	196	78.1	28.5	30.4
Detritus	184	73.3	27.4	29.2
Insects	182	72.5	27.3	29.1
Chironomid larvae	108	43.0	10.5	11.2
Ephemeroptera	56	22.3	8.7	9.3
Coleoptera	63	25.1	3.3	3.5
Plecoptera	57	22.7	3.1	3.3
Diptera	33	13.1	0.6	0.6
Hymenoptera	5	2.0	0.5	0.5
Chironomid pupa	5	2.0	0.4	0.4
Anisoptera	6	2.4	0.2	0.2
Zooplankton	94	37.5	4.3	4.6
Daphnia	50	19.9	3.0	3.2
Ceriodaphnia	25	10.0	0.6	0.6
Rotifers	23	9.2	0.7	0.7
Phytoplankton	31	12.4	2.1	2.2
Blue green algae	15	6.0	0.7	0.7
Green algae	4	1.6	0.4	0.4
Diatoms	12	4.8	1.0	1.1
Ostracods	54	21.5	2.0	2.1
Gastropods	10	4.0	1.4	1.5
Nematodes	51	20.3	0.7	0.7

Note that the percentage volume of the major food categories in bold adds up to 100%.

bynni waldroni feed on almost the same types of food items despite the difference in their distribution. *B. bynni* is distributed in the Nile system, in Egypt, Ethiopia, Kenya and Sudan (Lévêque and Daget, 1984; Bailey, 1994; Seegers et al., 2003; Getahun, 2007). This subspecies feeds on detritus, zoobenthos, crustaceans, insects and gastropods. The above feeding habit of *B. bynni bynni* agrees well with the results of the present study, but unlike many other studies on other *Barbus* species in Ethiopia, no piscivorous individuals were encountered in *B. bynni* from Lake Abaya. Admassu and Dadebo (1997) studied the feeding habits of *Barbus* sp. in Lake Hawassa and reported that the species is polyphagous, but according to these authors, the species tended to become piscivorous above 30 cm TL. Nagelkerke et al. (1994) studied the barbs of Lake Tana and reported that 8 out of 15 species were piscivorous, while the remaining 7 species were benthivorous and polyphagous. Likewise, the polyphagous feeding habit of *Barbus* species was reported by several authors from different fresh waters of the world.

De Graaf (2003) conducted a detailed study on the feeding habits of piscivorous barbs and found a high degree of piscivory even though piscivory is rare in

cyprinids due to lack of teeth, stomach and the associated digestive enzymes (de Graaf et al., 2010). In the absence of specialized piscivores many *Barbus* species may consume relatively large proportions of fish prey, especially at later stages during their ontogeny. Desta et al. (2006) suggested at least two feeding forms of *Lasiurus intermedius* in Lake Hawassa, Ethiopia: those that prey up on fish, and those that are polyphagous. In another extensive study on the feeding habits of a small barb, *Barbus paludinosus*, Desta et al. (2008) reported ostracods, zooplankton, mollusks, aquatic insects and fish to be the most important food categories.

Seasonal variation in the diet

The frequency of occurrence of zooplankton and phytoplankton in the diet significantly varied during the dry (n = 89) and wet (n = 162) seasons ($P < 0.05$). Similarly, the volumetric contribution of ostracods significantly differed during the two seasons ($P < 0.05$). On the other hand, both frequency and volumetric contributions of all other food items did not significantly differ during the two seasons (Table 2). Among the three

Table 2. Relative contribution of different food items in the diet of *B. bynni* during the dry (n = 89) and wet (n = 162) seasons.

Food item*	Frequency of occurrence (%)		Volumetric contribution (%)	
	Dry season	Wet season	Dry season	Wet season
Detritus	72.5 ^a	73.5 ^a	31.7 ^a	24.6 ^a
Macrophytes	84.3 ^a	76.5 ^a	30.1 ^a	30.8 ^a
Zooplankton	27.5 ^a	39 ^b	3.7 ^a	6.3 ^a
Rotifers	9.8	9	0.3	1.5
Ceriodaphnia	9.8	10	0.5	1.0
Daphnia	9.8	22.5	2.9	3.7
Insects	78.4 ^a	71 ^a	29.8 ^a	28.1 ^a
Chironomidae larvae	68.6	36.5	13.9	6.2
Chironomidae pupa	2.0	2	0.1	1.1
Diptera	-	16.5	-	2.0
Plecoptera	9.8	26	1.5	6.7
Coleoptera	15.7	27.5	2.5	5.5
Ephemeroptera	31.4	20	11.0	6.0
Anisoptera	2.0	2.5	0.2	0.1
Hymenoptera	2.0	2	0.5	0.5
Phytoplankton	31.4 ^b	7.5 ^a	2.2 ^a	2.3 ^a
Blue green algae	21.6	2	1.2	0.1
Green algae	3.9	1	0.5	0.1
Diatom	5.9	4.5	0.6	2.1
Ostracods	17.6 ^a	22.5 ^a	0.7 ^a	4.7 ^b
Gastropods	2.0 ^a	4.5 ^a	1.8 ^a	1.2 ^a
Nematodes	2.0 ^a	25 ^b	0.01 ^a	2.0 ^b

Note that the volume of the major food categories in bold adds up to 100%. *Values of respective food categories under the same category given different superscript letters are significantly different ($\alpha < 0.05$).

major food categories of *B. bynni*, detritus composed slightly higher volume during the dry season (31.7%) than in the wet season (26.4%). The contribution of macrophytes in the diet during the dry and the wet seasons (30.1 and 30.9%, respectively) and insects (29.7 and 28.1%, respectively) was fairly comparable (Table 2). Also, the overall volume of phytoplankton in the guts was comparable during the dry (2.2%) and wet (2.3%) seasons. The importance of zooplankton in the diet increased during the wet season (6.3%) compared to the dry season (3.7%). Similarly, ostracods and nematodes were consumed considerably more during the wet season than in the dry season, while gastropod consumption remained fairly constant during the two seasons (Table 2).

Although the total volume of insects in the diet remained similar during the dry and wet seasons, the contribution of the different taxa considerably varied during the two periods (Table 2). During the dry season, Chironomidae larvae and Ephemeroptera composed most of the insect bulk consumed by *B. bynni* in Lake Abaya (13.9 and 11.0%, respectively). Whereas their contribution dropped by about 50% in the wet season

(6.2 and 6% by volume, respectively).

On the other hand, the contribution of Plecoptera increased from 1.5 to 6.7% by volume, and that of Coleoptera increased from 2.5 to 5.5% by volume during the wet season compared to the dry season (Table 2). Comparing the two seasons, *B. bynni* consumed a fairly diverse group of insects during the wet season, whereas only two insect taxa composed most of the insect bulk consumed during the dry season.

Among zooplankton, *Daphnia* sp. was the most important during both seasons, but its contribution increased in the wet season than in the dry season. Also, the significance of the other two less important zooplankton (rotifers and *Ceriodaphnia* sp.) relatively increased in the wet season than in the dry season. Considering phytoplankton taxa, diatoms made up nearly all algal volume eaten during the wet season whereas, blue greens together with some greens and diatoms shared the dry season algae diet (Table 2).

The results of the present study have shown no significant difference on the feeding habits of *B. bynni* during the dry and wet seasons although there were some variations in the proportion of certain food

categories during the two seasons. The proportions of macrophytes, zooplankton, ostracods and nematodes were higher during the wet season while the proportions of detritus, insects, phytoplankton and gastropods were higher during the dry season. This difference in the proportions of the different food categories could be due to the difference in the availability and emergence of various food items during dry and wet seasons. Kolding (1989) observed seasonal migration of *B. bynni* from inshore areas to offshore habitats in Lake Turkana (Kenya). According to this author, during the wet season with high turbidity the population tends to migrate to inshore areas with progressive offshore movement as the water clears during the dry season (Kolding, 1989). Admassu and Dadebo (1997) studying *Barbus* sp. in Lake Hawassa (Ethiopia) and Dadebo et al. (2013) working on *L. intermedius* in Lake Koka (Ethiopia) reported seasonal variation in the diet of the studied fish species. The present study is in agreement with the above works in that insects were more important during the dry season while macrophytes and other invertebrates were more important during the wet season (Admassu and Dadebo, 1997; Dadebo et al., 2013). In general, seasonality did not affect the feeding behavior and the type of prey organisms of *B. bynni* in Lake Abaya because the majority of the food items showed no significant seasonal differences.

Ontogenetic dietary shift

SDOI revealed no significant variation in the diet of the different size classes because percentage overlap was above 60% in all combinations of size classes (I and II: 97.2%; I and III: 75.5%, I and IV: 62.4%; II and III: 73.9%; II and IV: 64.4%; III and IV: 86.3%). In general, the contribution of animal origin food was high in the diet of smaller size classes whereas this component declined as the fish grew in size (Figure 3). In fish below 40 cm TL, insects were important in the diets and the contributions of detritus and macrophytes remained more or less unchanged with size of fish. However, in the diets of *B. bynni* above 40 cm TL, the fish depended only on detrital matter and macrophytes for its nourishment (Figure 3). Among the minor food items, zooplankton were relatively important in the diet of fish less than 40 cm TL, but they were absent in the diets of larger fish. Similarly, the significance of phytoplankton, ostracods, gastropods and nematodes was visible in the diets of fish below 40 cm TL, whereas they were absent in the diets of larger fish (Figure 3).

Ontogenetic diet shift has been shown to occur during the life of many fish species, and prey size is generally positively correlated with fish size (Desta, 2007). A fundamental characteristic of fish is that individuals increase considerably in size, which is usually associated

with changes in food resource use (Desta et al., 2006). Based on the results of the present study, slight ontogenetic dietary change was noted. Small fish (<20 cm TL) and intermediate size fish (20 to 40 cm TL) predominantly fed on insects, followed by detritus and macrophytes. The composition of the diet of large fish (>40 cm TL) was different from the lower size classes because large fish exclusively fed on only food of plant origin, detritus and macrophytes comprising the total volume of the food categories.

Morphometric relationships

The relationships between TL and TW of males (11.6 to 35.8 cm TL; 14.2 to 359.2 g TW), females (13.4 to 50.0 cm TL; 15.9 to 1,200 g TW) and both sexes combined was expressed by the following regression equations:

$$\text{Males: TW} = 0.0033\text{TL}^{3.277}, R^2 = 0.989, n = 144, p < 0.001 \quad (3)$$

$$\text{Females: TW} = 0.0041 \text{ TL}^{3.207}, R^2 = 0.981, n = 148, p < 0.001 \quad (4)$$

$$\text{Combined: TW} = 0.0036\text{TL}^{3.245}, R^2 = 0.986, n = 292, p < 0.001 \quad (5)$$

The relationships between TL and FL (FL = 0.866TL - 0.316, $R^2 = 0.997$, $n = 292$, $p < 0.001$), TL and SL (SL = 0.806TL - 0.949, $R^2 = 0.995$, $n = 292$, $p < 0.001$) and FL and SL (SL = 0.929FL - 0.632, $R^2 = 0.995$, $n = 292$, $p < 0.001$) were all linear and statistically significant. As far as our knowledge goes, no study was found on morphometric relationships of *B. bynni* in African water bodies. Admassu and Dadebo (1997) studying a related species (*Barbus* sp.) in Lake Hawassa found slightly allometric growth pattern with a b value of 3.14

Conclusions

The food categories consumed by *B. bynni* were, macrophytes, detritus, insects, zooplankton, phytoplankton, ostracods, gastropods, and nematodes suggesting that *B. bynni* are a polyphagous fish species in Lake Abaya. No seasonality in diet was observed, however, there was an ontogenetic change in diet. Smaller size classes (<19.9 cm TL) predominantly relied on insects, detritus and macrophytes while medium sized fish (20 to 39.9 cm TL), depended mainly on insects, macrophytes and detritus. On the other hand, larger fish (>40 cm TL) fed only on detritus and macrophytes. The growth pattern of *B. bynni* in Lake Abaya was found to be allometric because the slope of the relationship (b) was 3.25, which is a value considerably higher than 3.

Conflict of Interests

The authors have not declared any conflict of interests.

Figure 3. Volumetric contributions (%) of the different food categories in the diet of different size classes of *B. bynni* in Lake Abaya, as an average for the dry and wet season.

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