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DIET COMPOSITION, LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR OF *BARBUS* SPECIES RÜIPPELL, 1836 (PISCES: CYPRINIDAE) IN LAKE AWASSA, ETHIOPIA

Demeke Admassu[1] and Elias Dadebo[2]

[1] Department of Biology, Addis Ababa University
PO Box 1176, Addis Ababa, Ethiopia

[2] Department of Animal Sciences and Rangelands Management
Awassa College of Agriculture, PO Box 5, Awassa, Ethiopia

ABSTRACT: Length-weight relationship, condition factor and composition of the diet of *Barbus* sp. in Lake Awassa were studied from monthly samples taken between December 1987 and September 1988. Total length and total weight of the fish were curvilinearly related (b = 3.14). Fulton's as well as relative condition factors did not vary between months and between sexes. *Barbus* sp. in Lake Awassa was considered to be polyphagous, because its diet was found to be composed of a diverse group of food items. Insect larvae (mainly chironomids), fruits, fish (mainly *Oreochromis niloticus)* and molluscs were the major food items of the fish whereas crustacean zooplankton, ostracods, nematodes and hydracarines were minor food items. Detritus and sand grains were also ingested by several individuals. The dominance of benthic food and the presence of sand in the gut indicate that the fish feeds mainly near the bottom. Although the fish is generally polyphagous, there were seasonal, individual and size-based differences in food and feeding habits. Thus, insects contributed more to the diet in the dry season whereas fruits, fish and molluscs contributed more in the wet season. This could probably reflect seasonal differences in availability between the food items. In addition, some individuals appeared to feed selectively on particular food items which could be a mechanism by which competition for food is minimised. Furthermore, individuals between 20.5 and 32.0 cm in length fed similar amounts of the major food items except that insects were taken at a relatively larger proportion. Fish larger than 31.5 cm appeared piscivorous. The degree of piscivory found in *Barbus* sp. in Lake Awassa was unexpectedly high, but as is the case in other cyprinids, it is believed to be due to the absence of specialised piscivores in the lake. The results of the study may also suggest that, as is the case in Lake Tana, the large *Barbus* of Lake Awassa may contain more than one morphotype, possibly more than one species. Thus, detailed taxonomic study is needed.

Key words/phrases: ***Barbus*** **sp., bottom feeder, Lake Awassa, piscivory, polyphagous**

INTRODUCTION

The genus *Barbus* (Fam. Cyprinidae) is widely distributed in African freshwaters (Cambray, 1983). In Ethiopia, the genus occurs in the River Awash and in several other rivers in the basins of Omo-Turkana, Chew-Bahir, Abaya--Chamo, Wabi-Shebelle and the Nile (Shibru Tedla, 1973; Golubtsov and Krysanov, 1993; Dgebuadze *et al.*, 1994). It also occurs in almost all of the lakes of the country. The most diversified *Barbus* fauna in Ethiopia is found in Lake Tana where 14 distinct morphotypes have recently been distinguished based on differences in external morphology and feeding habit (Nagelkerke *et al.*, 1994, 1995). Whether or not these are isolated species is yet unsettled, however, it seems probable that all of them originated from *B. intermedius* (Nagelkerke *et al.*, 1994).

Barbs are important components of the fisheries of Ethiopia (Mebrat Alem, 1993). The current annual total fish landing from the major waters of Ethiopia is about 6380 t from which 365 t is due to *Barbus* (LFDP, 1995). About 92% of the *Barbus* catch is from Lake Tana, and is composed of the various morphotypes. In addition, the annual catch of *Barbus* sp. from the other lakes ranges from 5 t (Lake Zwai) to 12 t (Lakes Koka and Awassa) (LFDP, 1995). Thus, this species is being exploited to a considerable degree in Ethiopia.

Matthes (1963) suggested that the genus *Barbus* can be split into distinct groups based on studies on feeding morphology and feeding habit. Therefore, a study on the food and feeding habit of this genus is an important development. Cyprinids do not have a true stomach (Matthes, 1963). However, the region of the gut between the oesophagus and the first bend in the tract contains food items that can easily be identified (Donnelly, 1982). Therefore, knowledge on the food habit of this fish is based on examination of the contents in this region of the gut.

In general, *Barbus* species are facultative feeders having distinct preferential diets, but they are also able to change their feeding habit (Matthes, 1963). Insect larvae and pupae form by far the most important food of several species (Donnelly, 1982; Cambray, 1983; Lowe-McConnell, 1987; Nagelkerke *et al.*, 1994). However, species like *B. altianalis* in Lake Victoria principally feed on

gastropods (Corbet, 1961). Other items ingested by various species include Crustacea, Ostracods, Bivalvia, fish and macrophyte fruits and shoots (Corbet, 1961; Donnelly, 1982; Lowe-McConnell, 1987; Nagelkerke *et al.*, 1994). Filamentous algae, diatoms and desmids are, to a limited extent, ingested by certain *Barbus* spp. (Corbet, 1961; Cambray, 1983). Sand and detritus are also ingested by several species indicating a bottom feeding habit (Corbet, 1961; Mraja, 1982; Cambray, 1983; Nagelkerke *et al.*, 1994). Moreover, the diet of *Barbus* spp. varies seasonally and according to the size of the fish (Corbet, 1961; Donnelly, 1982; LoweMcConnell, 1987).

Piscivory is rare in cyprinids in general (Matthes, 1963), but it seems to occur in waters where other specialised piscivores are rare or absent (Matthes, 1963; Nagelkerke *et al.*, 1994). Nagelkerke *et al.* (1995), for instance, found that among the 14 Barbus-morphotypes of Lake Tana, 8 are mainly piscivorous.

Barbus sp. is believed to be abundant in Lake Awassa; next only to the dominant *Oreochromis niloticus*. Thus, the Barbus-fishery in Ethiopia in general and in Lake Awassa in particular is believed to develop in the future. Therefore, knowledge on some aspects of its biology will be useful to utilise the stock properly, and also to understand the role of the fish in the ecology of the lake. Hence, the specific objectives of the present study were: (1) to investigate the length-weight relationship and the condition factor, and (2) to study the food and feeding habits of the fish, and to investigate if these vary seasonally and with the size of the fish.

Lake Awassa (Lat.: 6°33′ to 7°33′N; Long.: 38°22′ to 38°29′E) is the smallest (surface area: 88 km^2; mean depth: 11 m) of a series of seven natural rift valley lakes in southern Ethiopia. The region where Lake Awassa is located is characterised by a short dry season (November to February) and a long rainy season (March to October) (Daniel Gamatchu, 1977). Electrical conductivity (K_{20}) of the lake varies between 730 and 825 μmhos cm^{-1}, with an increase in the dry season and a decrease in the wet season (Elizabeth Kebede and Amha Belay, 1994). Nitrate appears to be the nutrient that most limits phytoplankton productivity in Lake Awassa (Elizabeth Kebede and Amha Belay, 1994). The dominant phytoplankton species in Lake Awassa are *Lyngbya nyassae*, *Botryococcus braunii* and *Microcystis* spp. (Elizabeth Kebede and Amha Belay,

1994) whereas the dominant zooplankton species are *Mesocyclops aequatorialis, Thernwcyclops consimilis* and *Diaphanosoma excisum* (Seyoum Mengistou and Fernando, 1991). Chironomids, ostracods and oligochaetes are numerically among the dominant members of the benthic fauna in Lake Awassa (Tilahun Kibret, 1985). Fish species inhabiting the lake are *O. niloticus, Clarias gariepinus, Barbus sp., B. amphigramma, Garra* sp. and *Aplocheilichthys sp.*

MATERIALS AND METHODS

Monthly samples ranging in number from 23 to 47 were taken using a fleet of gill nets during the period December 1987 to September 1988 (except in March). The fleet was 152 m long and 2.4 m deep, and consisted of six gill nets whose stretched mesh sizes ranged from 50.0 mm to 112.5 mm by increments of 12.5 mm. The fleet was set, mostly between 1600 and 0900 h, at the surface of the lake (depth about 3 m) at a fixed site throughout the study.

Total length (TL) and total weight (TW) were measured from a total of 267 fish. The sex of each specimen was identified by inspecting its gonads, and sex ratio in each sample was calculated. Length-weight relationship was calculated using least squares regression analysis. Fulton's condition factor was calculated as TW in percent of TL^3 (Le Cren, 1951), and relative condition factor was calculated as TW divided by (aTL^b), where 'a' is the intercept and 'b' is the slope of the length-weight regression (Bagenal and Tesch, 1978). Length-weight relationship and condition factor were calculated for fish between 11.1 and 56.0 cm and between 10.5 and 2000.5 g. The values of condition factors were statistically tested (ANOVA, Sokal and Rohlf, 1981) to determine if they varied between sexes and between months.

The contents of the gut of each specimen were preserved in 5% formaldehyde solution for a later microscopic examination in laboratory. Gut content samples were not taken from fish caught in February, April and May. In the laboratory, the food items were identified to the lowest taxa possible using descriptions from various sources (Mamaril and Fernando, 1978; Pennak, 1978; Edington and Hildrew, 1981). The relative importance of each food item was analyzed using the frequency of occurrence, numerical abundance and the points methods

(Hynes, 1950; Windell and Bowen, 1978). The points method was used only for the main food items after they were classified into major groups, i.e., insects, fruits, fish and molluscs. The points method, first described by Hynes (1950), was used as modified by Frost (1977) and Donnelly (1982). Points were assigned to each food item based on a visually determined contribution of the item relative to the degree of fullness of the gut. A half-full stomach, for instance, contained an estimated 1/2 insects, 1/4 fruits; 1/4 molluscs and no fish. The allotted points were 50, 25, 25 and 0 for insects, fruits, molluscs and fish, respectively. The points were then divided by 100 and multiplied by fullness index which was determined before dissection by assigning semi-quantitative indices, viz. 100 = full, 75 = 3/4 full, 50 = 1/2 full, 25 = 1/4 full, 12 = 1/8 full and 6 = traces of food. In the half-full stomach (fullness index = 50) mentioned above, the points relative to the fullness index of the gut were 25, 12.5, 12.5 and 0 for insects, fruits, molluscs and fish, respectively.

A combination of frequency of occurrence and the points method was also used by grouping the percentage points of each food item in 10% classes (i.e., 0-10%, 10-20%, etc.), and plotting this value together with the frequency of occurrence in a combined frequency distribution.

Results from the points method were statistically tested for seasonal and fish size differences (G-test, Sokal and Rohlf, 1981). The relationship between feeding habit and fish size was investigated based on results obtained from the points method.

RESULTS

A total of 131 females and 136 males were caught throughout the study. Sex ratio in the total catch and in monthly catches did not vary significantly from 1:1 (Chi-square test, $p < 0.05$). Length composition and sample size of the fish used in this study are shown in Fig. 1. From a total of 127 fish dissected for gut content analysis, 23 (18.1%) had empty guts.

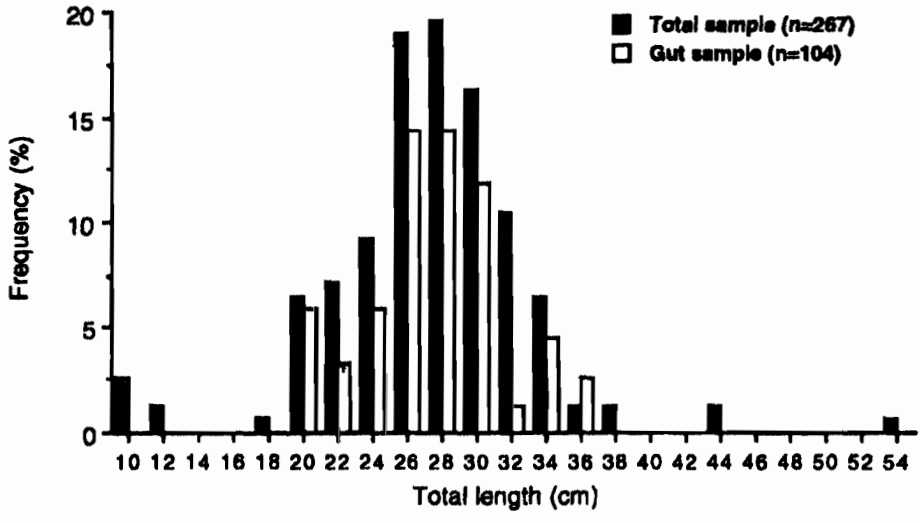

Fig. 1. Length-frequency (%) of *Barbus* sp. from Lake Awassa in the total sample and in the sample taken for gut content study.

Length-weight relationship and condition factor

The length-weight relationship of *B. intermedius* in Lake Awassa was significant (ANOVA, $p=0.001$), and curvilinear (Fig. 2). Both Fulton's and relative condition factors of the fish did not vary significantly between months or between sexes (ANOVA, $p>0.05$). The values for the sexes were combined. Monthly values (mean $\pm$ standard error) of Fulton's condition factor ranged from 0.89 ± 0.15 to 0.98 ± 0.13, whereas that of relative condition factor ranged from 0.96 ± 0.13 to 1.02 ± 0.22 (Table 1). Condition factors did not vary significantly (ANOVA, $p>0.05$) between the dry (December-January) and the wet (February--September) seasons. Fulton's condition factor was 0.95 ± 0.13 in the dry season and 0.85 ± 0.18 in the wet season. Relative condition factor was 0.99 ± 0.22 in the dry season and 1.00 ± 0.19 in the wet season.

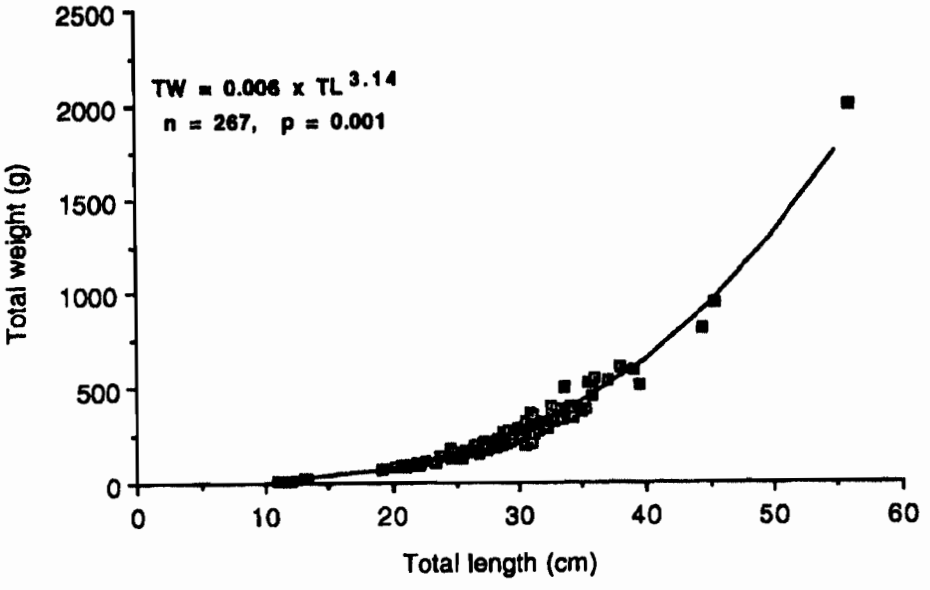

Fig. 2. Length-weight relationship of *Barbus* sp. in Lake Awassa.

Table 1. Mean monthly values of Fulton's (FCF) and relative (RCF) condition factor of *Barbus* sp. in Lake Awassa. SE is standard error and n is sample size.

Month	FCF±SE	RCF±SE	n
December	0.96±0.11	0.99±0.21	23
January	0.97±0.13	1.00±0.22	26
February	0.91±0.21	0.98±0.15	27
April	0.94±0.21	0.96±0.13	28
May	0.98±0.13	1.01±0.14	29
June	0.93±0.11	0.98±0.13	30
July	0.96±0.15	1.01±0.15	26
August	0.89±0.15	0.96±0.16	31
September	0.91±0.21	1.02±0.22	47

Composition of the diet

The diet of *Barbus* sp. in Lake Awassa was composed of diverse groups of organisms (Table 2). Algae were not found in the gut except two genera of diatoms which were rare. Crustaceans were represented by the cladoceran *Diaphanosoma excisum* and by unidentifiable copepods. Nematodes were found in the gut of some specimens, but it was not possible to determine whether they were ingested as food or they were parasites to the fish. Insects were the most diverse organisms in the diet of the fish, and were represented by young stages and adults belonging to six major groups (Table 2). Shells of gastropod snails, of which three genera were identified, were also found in several specimens. Other fish were also ingested by several *Barbus* individuals, but most of them were partly digested and unidentifiable. However, *O. niloticus* appeared the most common fish ingested by *Barbus* sp. Some of the unidentifiable fish looked like the cyprinodont *Aplocheilichthys* sp. The other important food items of *Barbus* sp. in Lake Awassa were fruits. Detritus and sand grams were also ingested by several specimens.

Generally, insects, macrophyte fruits, fish and molluscs were the major food items whereas the others were minor food items of the fish. Based on the frequency of occurrence method, the main items in descending order of importance were insects (93.2%), macrophyte fruits (63.5%), fish (34.6%) and molluscs (28.8%) (Table 3). Frequency of occurrence for the other items ranged from 3.9% (hydracarines, crustaceans and ostracods) to 9.6% (nematodes). Numerically, insects and macrophytes contributed each to about 48% of the food items. The numerical importance of each of the remaining items was considerably low: molluscs < 3%, fish < 1%, and the minor items < 2% (Table 3). Based on the points method insects, fish, molluscs, fruits and the minor items contributed 44, 29.8, 18.5, 6.7. and 1% of the bulk of the food-ingested by *Barbus sp.*, respectively.

Among insects, chironomid larvae were the most important food of *Barbus sp.* in Lake Awassa, because they were encountered in 81.7% of the specimens and constituted more than 30% of the total number of the food items. Although the corresponding values for the other insects were much lower, Ephemeroptera and Trichoptera were the second important insects in the diet (Table 3).

Table 2. Food items identified from the gut of Barbus sp. from Lake Awassa.

Algae
Bacillariophyceae (rare)
Navicula sp., Cymbella sp.
Crustacea
Cladocera (*Diaphanosoma excisum*)
Copepoda (unidentified)
Ostracoda
Nematoda
Insecta
Chironomidae larvae
Ephemeroptera nymphs
Tricoptera larvae & pupae
Odonata nymphs
Coleoptera
Hemiptera
Hydracarina
Mollusca (gastropods)
Bulinus sp., *Physa* sp., *Anisa* sp.
unidentified
Pisces
Oreochromis niloticus
unidentifiable (probably *Aplocheilichthys* sp.)
Macrophytes (fruits, shoots & roots)
Detritus
Unidentifiable animal remains
Sand grains (abundant)

Table 3. The relative importance of various food items to the diet of *Barbus* sp. in Lake Awassa. O, frequency of occurrence; N, numerical abundance; n, number of fish in which the items were found.

Food Items	O(%)	N(%)	n
Chironomid larvae	81.7	32.6	85
Ephemeroptera nymphs	58.7	6.4	61
Trichoptera larvae & pupae	55.8	7.8	58
Odonata nymphs	31.7	1.3	33
Coleoptera	3.9	<1.0	4
Hemiptera	3.9	<1.0	4
Hydracarina	3.9	<1.0	4
Copepoda	3.9	<1.0	4
Cladocera	3.9	<1.0	4
Ostracoda	3.9	1.2	4
Nematoda	9.6	<1.0	10
Mollusca	28.8	2.3	30
Fish	34.6	<1.0	36
Macrophyte fruits	63.5	48.5	66

Frequency distribution of percentage points is an indirect indication of the number of fish feeding on a particular food item, and also the relative volumetric contribution of the food items (Fig. 3). Thus, insects constituted 90% of the bulk of the food for 14% of the barbs examined, and were the sole food (i.e., 100% of the food bulk) for 23% of the sample. Also, it is evident from Fig. 3 that molluscs were 90% of the food bulk in 4.5% of the fish, but they were not 100% of the bulk in any specimen. Moreover, fish were found to be 90% and 100% of the food bulk in 3% and 25% of the sample, respectively. Fruits of macrophytes were the only food items (100%) in 11.0% of the fish.

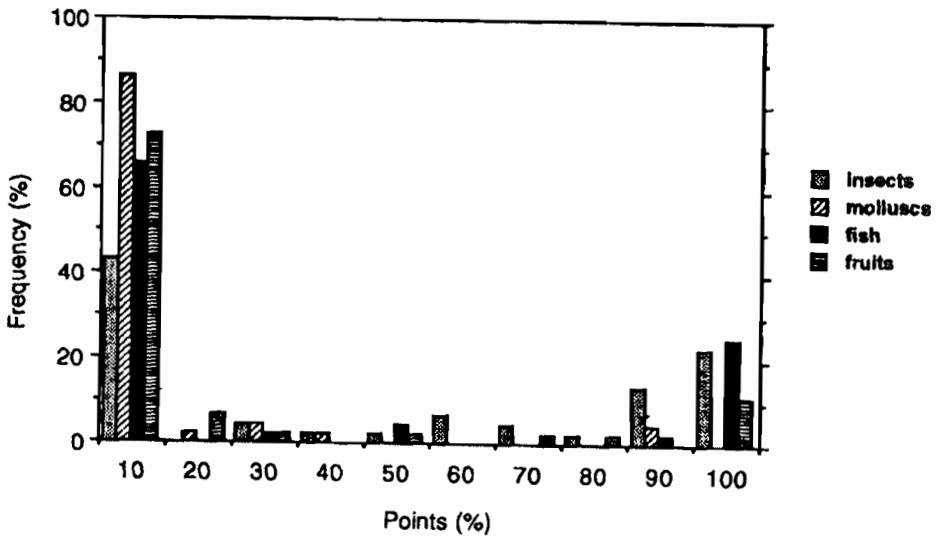

Fig. 3. Percentage frequency distribution of points (upper class limit) awarded to the main food items of *Barbus* sp. in Lake Awassa.

The percentage points of the major food items varied significantly between the dry and the wet seasons (G-test, $p < 0.05$). Insects contributed more in the wet than in the dry season whereas fruits, fish and molluscs contributed more in the dry than in the wet season (Fig. 4a).

Barbus sp. between 20.5 and 32.0 cm TL were found to feed on the various food items at approximately equal proportions, but insects appeared to be dominant (Fig. 4b). In contrast, individuals larger than 31.5 cm were found to be mainly piscivorous, but small amounts of insects and fruits were also eaten by a few individuals. The minor food items (crustaceans, hydracarines, ostracods and nematodes) were not ingested by fish larger than 30.5 cm (Fig. 4b).

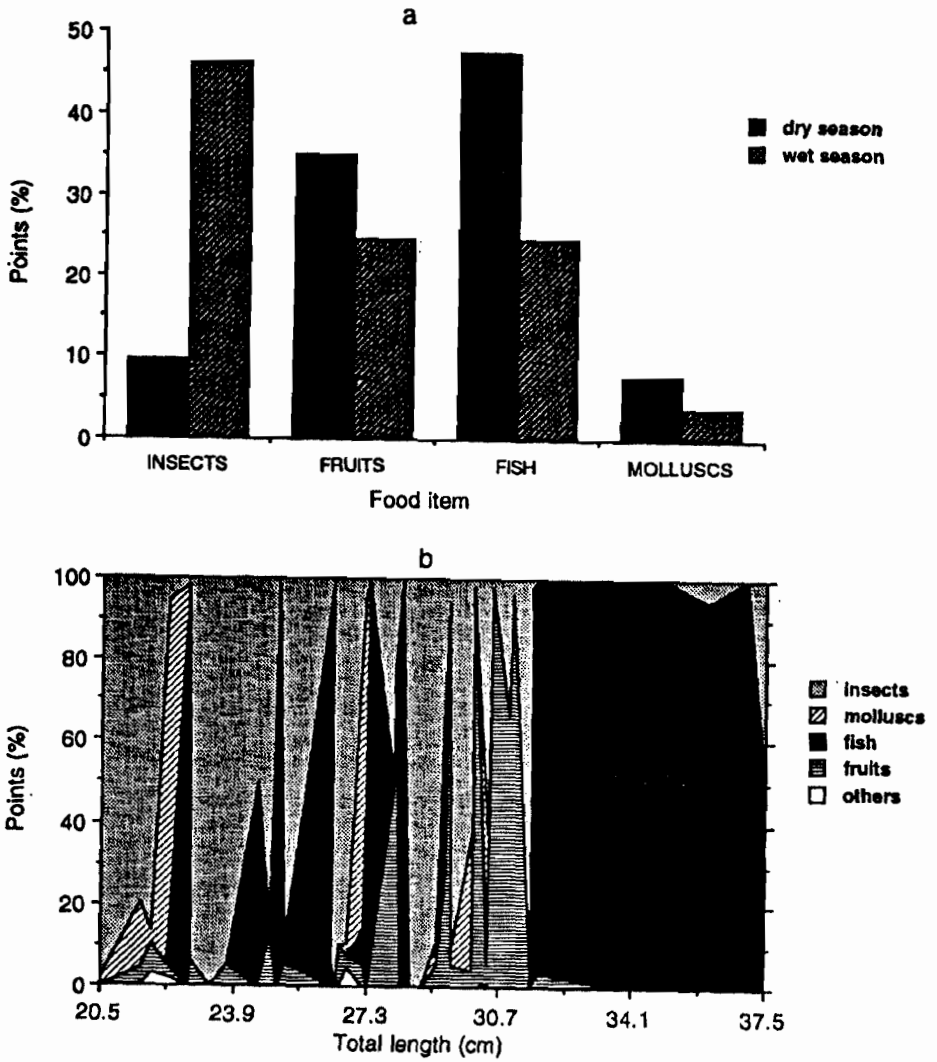

Fig. 4. Variation in composition of the food of *Barbus* sp. in Lake Awassa between the dry and the wet seasons (a), and with total length of the fish (b).

DISCUSSION

The length-weight relationship (b = 3.140) of *Barbus* sp. in Lake Awassa indicates that the fish grow nearly isometrically (Ricker, 1975). The value of b calculated in this study is comparable to those reported for some of the morphotypes of *Barbus* in Lake Tana (Nagelkerke *et al.*, 1994).

The study showed that *Barbus* sp. in Lake Awassa feeds on a variety of food items, and it can thus be considered as polyphagous. Polyphagy is typical for cyprinid fishes (Matthes, 1963; Cambray, 1983; Sibbing, 1991), and this may have contributed to the highly adaptable nature of *Barbus* spp in Africa, which in turn must have resulted in explosive speciation whenever conditions are favourable (Matthes, 1963). Polyphagy has also been reported by Nagelkerke *et al.* (1994) for some of the morphotypes in Lake Tana.

The frequent occurrence of sand and the dominance of benthos (i.e., insect larvae and pupae, molluscs and macrophyte fruits) in the gut of *Barbus* sp. indicate that the fish is mainly a bottom feeder. This could also be the reason why diatoms, which settle to the bottom in calm water conditions (Wetzel, 1983), were the only algae found in the gut of some fish. However, as is the case for *B. anoplus* in Lake Le Roux, South Africa (Cambray, 1983), the rare occurrence of diatoms in the gut may indicate that they were ingested accidentally when the fish were feeding on the bottom.

Donnelly (1982) found zooplankton and ostracods to be important food for juvenile *B. mattozi* in Mtsheleli Dam, Zimbabwe. Similarly, ostracods are the most important food of *B. bynni* in Lake Turkana (Mraja, 1982) and *B. anoplus* in Lake Le Roux (Cambray, 1983). These food items are of minor importance for the barbs of Lake Awassa. In addition, oligochaetes are important food for some barbs elsewhere (Spataru and Gophen, 1987), but were not encountered in this study. Furthermore, Tilahun Kibret (1985) reported that ostracods and oligochaetes are among the dominant members of the benthic fauna of Lake Awassa. Thus, it appears that some of our results may have been influenced by the lack of small fish in the study which in turn could be due to sampling fish from a single location using one type of fishing gear. Nevertheless, our results

are not surprising as fish diet can vary even within a lake depending on feeding ground, season and fish size (Lowe-McConnell, 1987).

The study showed that composition of the diet of *Barbus* sp. in Lake Awassa varies with its size and between the dry and the wet seasons (Figs. 4a and 4b). Within the size range studied, the fish is omnivorous at sizes between 20.5 and 32.0 cm, but it appears to be piscivorous at larger sizes. Similarly, *B. mattozi* is planktivore when juvenile and an omnivore at sizes between 12.0 and 25.0 cm whereas entirely a piscivore at larger sizes (Donnelly, 1982). Other species showing a shift in diet with increase in size include *B. altianalis* in Lake Victoria (Corbet, 1961) and *B. longiceps* in Lake Kinneret, Israel (Spataru and Gophen, 1987).

Among the 104 individuals examined in this study, 34.6% of them had ingested other fish, and fish were the sole food in 25% of the specimens. The same has been reported for the majority of the Barbus-morphotypes in Lake Tana (Nagelkerke *et al.*, 1994). Since cyprinids lack oral teeth, they are morphologically limited to eat other fish, and hence, piscivory is rare in cyprinids (Matthes, 1963; Sibbing, 1991). Thus, the extent of piscivory in large (>32 cm TL) *Barbus* sp. in Lake Awassa appears unexpectedly high, as it is in Lake Tana (Nagelkerke *et al.* 1994 & 1995). Piscivorous cyprinids however, seem to occur where other specialised piscivores are rare or absent (Matthes, 1963; Sibbing, 1991). In Lake Awassa, *C. gariepinus* feeds on other fish, but it is an omnivore and not a specialised piscivore (Elias Dadebo, 1988). Thus, the absence of specialised piscivores in the lake could have favoured *Barbus* sp. to include fish as a major component of its diet.

The diet of a fish depends on the availability of the food in the environment. Thus, the seasonal difference in the relative contribution of the major food items of *Barbus* sp. in Lake Awassa could reflect seasonal differences in their availability. Vegetative growth of macrophytes in Lake Awassa is extensive during and immediately after the rainy season (personal observation). Thus, fructification and the eventual shedding of fruits may take place at the beginning of the dry season, hence fruits becoming more available in the dry season. In addition, other fish, particularly *O. niloticus*, appear to be relatively more available in the dry season, because recruitment of juvenile *O. niloticus* in Lake

Awassa is intensive between January and March and less intensive between July and September (Yosef T-Giorgis and Casselman, 1995; Demeke Admassu, 1997). There is no seasonal difference in the abundance of insects in Lake Awassa (Tilahun Kibret, 1985). Thus, their decrease in the diet of *Barbus* sp. in the dry season could be due to the inclusion of larger quantity of macrophyte fruits, other fish and molluscs in the diet. Information on seasonal abundance of molluscs in Lake Awassa is not available.

Macrophyte fruits, insects and other fish are each the sole food for a large number of barbs. These food items are ingested by fish of similar length range, and also both in the dry as well as in the wet seasons (Fig. 4). Thus, there appears to be a selection of a specific food item by some individuals which could be a mechanism by which competition for food is reduced among individuals. In addition, the results also suggest that the taxonomic status of the barbs of Lake Awassa may be more complicated than expected. It is also possible that the barbs of Lake Awassa may contain more than one morphotype and/or species as has been shown to be the case for Lake Tana barbs by Nagelkerke *et al.* (1994). A similar study is recommended on the barbs of Lake Awassa.

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