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The food habits of an herbivorous fish (*Oreochromis niloticus* Linn.) in Lake Awasa, Ethiopia

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Abstract

The natural food of *Oreochromis niloticus* in Lake Awasa was studied from the stomach contents of 10 fish measuring 18–32 cm (standard length) monthly from August 1984 to April 1986. *Chroococcus, Oscillatoria* and *Botryococcus* were found to be important food items in the diet. Animal foods were observed on rare occasions and these were mainly Rotifera. Blue-green algae as a group contribute about 28.1% of the ash free dry weight (AFDW) whereas diatoms and green algae (excluding *Botryococcus*) make 2.31% and 2.39% of AFDW, respectively. *Botryococcus*, detritus and other algae comprised 67.2% of AFDW and it was suspected that more than half of this was contributed by *Botryococcus*. Blue-green algae, which were especially abundant in the diet during the dry season, November–February, are nutritionally most important. Seasonal variation in algal species composition could influence the quality of food ingested by the fish.

Introduction

Many workers studying the food of freshwater fishes have based their conclusions on the study of the contents of the stomach (Hynes, 1950; Spataru, 1976; Maitipe & De Silva, 1985; Hyslop, 1980; Windell, 1978; Windell & Bowen, 1978). There are basically three goals for such studies: 1) to describe a diet; 2) to compare diets of different groups of fish and 3) to assess the nutritional value of the diet or its components. Numerical analysis is usually the best way to establish relative abundance but data from numerical analysis provides little information on food value. Gravimetric analysis by dry weight is the best approach, since it quantifies the dry biomass that has potential food value (Windell & Bowen, 1978). However, many invertebrates and most algae are too small to weigh directly, and their weight must be estimated from their volume. Here, estimated wet volume is converted to dry weight using the conversion factor as 1 mm^3 = 0.1 mg (Bowen, 1983). If the proportion of organic matter in the sample is known, it is also possible to convert dry weight into percentage organic matter.

The study of diet may also be used to describe seasonal variation in the nutritive value of the diet of a fish population (Windell & Bowen, 1978). The phytoplankton composition of an aquatic ecosystem is affected by biological (number of grazers), physical (light and temperature) and chemical (nutrients) factors (Wetzel, 1983). This means that there is variation in composition from lake to lake and throughout the year. In addition, the food value of algal species can vary widely both in quality and digestibility. These variations can easily affect an herbivorous fish, such as *Oreochromis niloticus*, that specializes in phytoplankton feeding. The condition of such a fish depends mainly on the availability of nutritionally desirable algal species. Quantitative determination of the components of the diet, their nutritive value and seasonal availability is essential to an understanding of environmental impacts on the condition and growth of *O. niloticus*. The present work was undertaken to obtain this quantitative dietary information using stomach content analysis.

Study area: Lake Awasa

Lake Awasa is located in the main Ethiopian Rift extending between latitudes from 6° 33′ to 7° 33′ N and longitudes from 38° 22′ to 38° 29′ E (Welcomme, 1972). The lake has a surface area of 88 Km^2 and a maximum depth of 22 m (J. Herrmann, pers. commun.). The conductivity of the water is about 850 $\mu S \cdot cm^{-1}$ and sodium and bicarbonate are the dominant cations and anions, respectively (Von Damm & Edmond, 1984; Kifle, 1985).

The lake is fringed by an extensive macrophyte zone consisting of *Cyperus* spp., *Nymphea caerulea*, *Potomogeton* spp., *Typha angustifolia* and *Paspalidium geminatum*. The littoral macrophyte region provides breeding grounds for spawning *O. niloticus* shelter for the juveniles and a feeding area for *Barbus* spp. and *Clarias gariepinus*, apparently the only other fish in the lake. The benthic fauna consists predominantly of ostracods, although chironomids, cyclopoids and Cladocera are also present (Kibret, 1985).

Materials and methods

Fish were caught monthly whenever possible using gill nets (100 mm stretched mesh) set overnight during 1984–86. On the following morning the fish were removed from the nets, taken to the laboratory, dissected and their stomachs isolated. About ten specimens with full stomachs were selected. Approximately half of the contents of each stomach were placed in a plastic bag containing 10% formalin, while the other half was transferred to a glass vial which was kept in an oven (100 °C) to dry. After drying, the contents were ground using a mortar and pestle and a known weight of the sample was ignited in a furnace (Fisher Isotemp Muffle Furnace 184A) at 550 °C for 4 hours, cooled and reweighed. The weight loss after ignition gives the weight of total organic matter in the sample.

Algae in formalin-preserved specimens were identified using descriptions from several sources (Prescott, 1970; Whiteford & Schumacher, 1973; Skuja, 1948; Trainor, 1978; Sze, 1986). The algal units were counted by the transect method of Lind (1974) and volumes were estimated assuming simple geometric shapes (sphere, rectangle and cylinder). The dimensions were measured by Olympus compound microscope fitted with an ocular micrometer (Mullin *et al.*, 1966; Sicko-Goad *et al.*, 1977; Nalewajko, 1966; Bellinger, 1974).

Filamentous algae of different sizes were measured and their average volume was estimated. Disruption of colonies of *Microcystis* was achieved by magnetic stirrer and the volume of individual cells was estimated. The dimensions of *Merismopedia* and *Scenedesmus* were measured as groups of eight and four cells, respectively. The biomass contribution of the colonial green alga *Botryococcus braunii* was difficult to estimate. Magnetic stirring of the preserved specimens did not dissociate and evenly distribute the colony. This alga also had a tendency to float in the suspensions. As such, the contribution of *B. braunii* was estimated indirectly. Once the proportions of all the algae in the food were calculated, the unaccounted biomass was assigned to *Botryococcus*. This had the disadvantage of overestimating the contribution of this alga, since detritus and rare algae would be included. However, visual assessment of the food indicated that very often more than 50% of the unaccounted biomass could be contributed by *B. braunii*.

Estimation of the contribution of different algal taxa to ash free dry weight (AFDW) required counting the cells/unit and determining their volumes. From the counts, volumes and percentage organic matter, the biomass of each algal genus in the food was estimated (Bowen, 1983; Getachew, 1987). In addition, the % abundance, % biomass and % occurrence were computed.

Results

Spirulina, Gloeothece, Oocystis, Tetraedron, Pediastrum and *Peridinium* were rarely encountered (Table 1). Animal foods were observed on rare occasions, and these were mainly Rotifera. *Chroococcus, Oscillatoria* and *Botryococcus* are important food items (Table 2). The mean biomass of the blue-green algae as a group for all samples comprised 28.1% of the AFDW whereas diatoms and green algae contributed 2.3% and 2.4% AFDW respectively. The rest is assumed to be the sum of *Botryococcus* and other organic materials, including detritus and a mixture of less abundant algae (Fig. 1). There was a significant seasonal difference ($P < 0.0001$) in abundance of *Chroococcus* and *Oscillatoria*, the algae that occurred in the stomach contents of all fish examined (Table 3). The blue-green algae were especially abundant during the dry season, November–February (Fig. 2). March samples for three years, 1984–86, and all other wet season samples showed that the blue-green algae were reduced to a greater or lesser extent. February samples of 1985, included for comparison, showed that the blue-green algae increased in proportion at this time of the year (Fig. 2). There appears to be a crash in their population at the beginning and end of the rainy season.

Table 1 The composition of algae from the stomachs of *Oreachromis niloticus* collected in Lake Awasa between August 1984 and April 1986.

CYNAOPHYTA
Spirulina (Rare)
Gloeothece (Rare)
Chroococcus
Oscillatoria
Merismopedia
Microcystis
Arthrospira
CHRYSOPHYTA
Navicula
Cymbella
Pinnularia
Nitzschia
PYRROPHYTA
Peridinium (Rare)
CHLOROPHYTA
Gleocystis
Scenedesmus
Ankistrodesmus convulatus
Ankistrodesmus falcatus
Oocystis (Rare)
Tetraedron (Rare)
Pediastrum (Rare)
Botryococcus braunii (abundant)

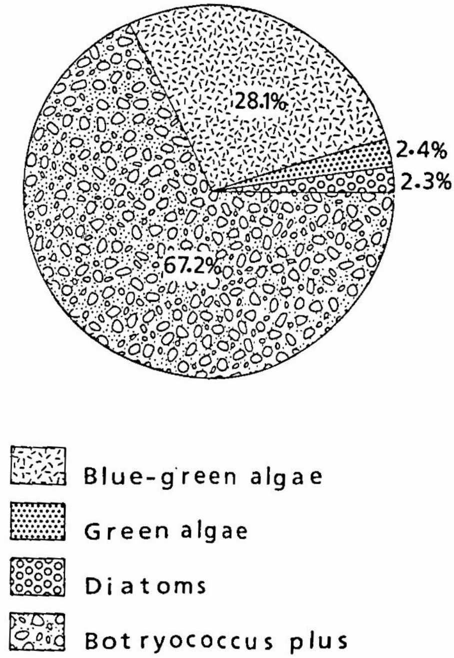

Fig. 1. Abundance (%AFDW) of the major groups of algae in the stomach of *O. niloticus* in Lake Awasa. (Green algae do not include *Botryococcus*.) All fish examined are included.

Table 2. Proportion of algae from stomach contents of *O. niloticus* as determined by different methods. O = Occurrence, N = Number, W = Weight, 'n' is the number of fish in which the algae were encountered in the transects examined. Fish collected between August 1984 – April 1986.

Algae	O(%)	N(%)	W(%)	%AFDW ± S.E.	n
Chroococcus	100	59.40	27.2	8.37 ± 0.38	124
Oscillatoria	100	19.60	53.4	16.30 ± 0.78	124
Merismopedia	69	0.63	3.3	1.34 ± 0.19	84
Microcystis	98	18.00	5.4	1.77 ± 0.13	107
Arthrospira	88	0.63	1.0	0.33 ± 0.03	107
Navicula	83	0.41	3.1	1.10 ± 0.11	102
Cymbella	20	0.05	0.6	0.66 ± 0.12	22
Nitzschia	23	0.06	0.5	0.63 ± 0.09	28
Pinnularia	40	0.11	0.4	0.26 ± 0.02	50
Gleocystis	89	0.61	3.6	1.23 ± 0.13	37
Scenedesmus	31	0.07	0.5	0.49 ± 0.05	66
A. falcatus[1]	53	0.17	0.7	0.37 ± 0.04	55
A. convulatus[2]	44	0.23	0.3	0.22 ± 0.02	111
Botryococcus	100	–	–	–	124

[1] *Ankisterodesmus falcatus,* [2] *Ankisterodesmus convulatus*

Table 3. Results of one-way ANOVA and SNK tests to determine if there were significant (a = 0.05) monthly differences in the biomass of two genera of algae in the stomach contents of fish examined.

Algae	F-value	d.f.	Sig.	SNK*
Chroococcus	9.36	8,81	P < 0.0001	2 1 12 9 8 11 4 3 10
Oscillatoria	13.12	8,81	P < 0.0001	2 1 9 11 12 4 8 3 10

* Monthly samples underscored by the same line are not significantly different.

Discussion

Different ways of estimating the abundance of algae, despite their inherent biases, indicate that *Chroococcus, Oscillatoria* and *Botryococcus* are important in the diet of *O. niloticus*. However, all of these methods do not account for the variable rates of digestion. The rate of digestion is particularly important in herbivorous fish that feed on plants; the structural materials, which may contain cellulose, chitin and lignin, are not susceptible to digestive enzymes. *Botryococcus* also contains botryococcenes, which are highly branched, long-chain hydrocarbons (Maxwell *et al.*, 1968; Gelpi *et al.*, 1968; Brown *et al.*, 1969; Douglas *et al.*, 1969) which may not be digestible. However, Moriarty (1973) ascertained that acid hydrolysis can break alga cells, releasing the contents. He and Moriarty and Moriarty (1973) showed that blue-green algae are digested and assimilated by *Oreochromis niloticus*. But it is not yet known if stomach acid disrupts the colony of *Botryococcus*. The high amount of intact *Botryococcus* colonies in the faeces indicates that such hydrolysis is unlikely. In this regard, the blue-green algae have a higher nutritional importance than *Botryococcus*. The presence of food items in the stomach does not necessarily show that the food is usable (Lagler, 1956). In addition, items that persist longer in a recognizable form in the stomach would appear to be more important in the diet, even though they would be nutritionally less important.

Detritus that is present in the food but not quantified can also provide substantial nutrition to the fish. Bowen (1980) has shown that *Oreo-*

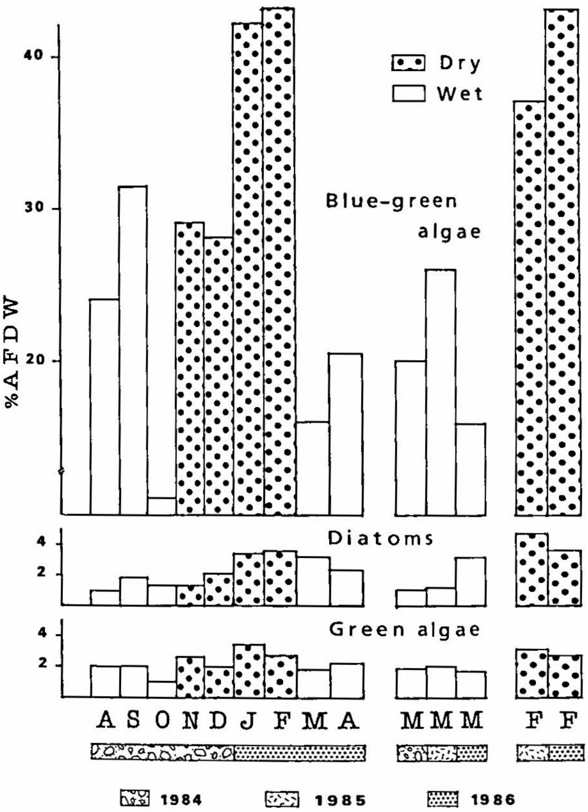

Fig. 2. Seasonal abundance (%AFDW) of the major algal groups in the stomachs of *O. niloticus* in Lake Awasa. (Green algae do not include *Botryococcus*).

chromis niloticus thrives very well on amorphous detritus that is abundant in Lake Valencia, Venezuela. The non-protein amino acids and the bacterial cells that are found in association with detritus are the important components that provide the bulk of the essential nutrition in this fish. De Silva *et al.* (1984), working with *Oreochromis mossambicus* in the reservoirs of Sri Lanka, and de Moor *et al.* (1986), in Hartbeespoort Dam in South Africa, have both shown that this fish does well on a detritus diet. In Lake Awasa the bottom is comprised of high organically rich sediments. This abundant food is obviously ingested by the other species, *Clarias gariepinus* and *Barbus* spp. (unpublished). Although *Oreochromis niloticus* feeds mainly on phytoplankton, it is not uncommon to find its stomach full of detritus. So, this food source is also probably important for *Oreochromis niloticus* in Lake Awasa.

In this work, one further step beyond that attempted by previous workers was taken to convert the bulk of the food material into percentages of ash free dry weight (%AFDW). With a reasonable estimate of assimilation efficiency for organic matter in different algae, it is possible to determine the importance of food in terms of energy. The relative contribution of algae to AFDW in the stomach shows that the bulk of the food is contributed by the blue-green algae and *Botryococcus*. Diatoms and green algae are equally represented in the food. Since diatom frustules are porous to enzymes, hydrolysis by enzymes can easily take place (Fish, 1951; Harbott, 1975; Spataru & Zorn, 1978). In this respect, the nutritional contribution of this group can also be quite substantial. The components classified with *Botryococcus*, detritus and other algae can supply additional nutrition. Even though bacteria were not found on the surface of *Botryococcus* (Z. Gebre-Mariam, pers. commun.), J. Green (pers. commun.) suspects that some Protozoa and Rotifera might attach themselves to *Botryococcus*. He observed Suctoria (Ciliophora) attached to *Botryococcus* colonies. The strategy to complement nutrition with protein-rich animal food is obviously advantageous. However, it is believed that free swimming zooplankton escape from the feeding currents generated by the fish (Moriarty & Moriarty, 1973). Relatively slow moving or attached zooplankton, Rotifera, or sessile Protozoa on algae are probably important sources of nutrition for fish in this lake.

The blue-green algae tend to increase in the diet of *O. niloticus* during the dry months, November–February. Seasonal variation in algal species composition could influence the quality of the food ingested by the fish.

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