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SEASONAL VARIATIONS DETERMINE DIET QUALITY FOR *OREOCHROMIS NILOTICUS* L. (PISCES: CICHLIDAE) IN LAKE TANA, ETHIOPIA

Getachew Teferra [1], S.H. Bowen, [2] Eyualem Abebe [3] and Zenebe Tadesse [3]

[1] Department of Biological Sciences, University of Botswana
Private bag 00704, Gaborone, Botswana

[2] Department of Biological Sciences, Michigan Technological University
Houghton, MI, 49931, USA

[3] Department of Biology, Bahir Dar Teachers' College
PO Box 79, Bahir Dar, Ethiopia

ABSTRACT: The diet composition and its use by *Oreochromis niloticus* in Lake Tana, Ethiopia, were studied from monthly samples taken over 13 months. The composition of the diet varied seasonally, with dramatic increases in quality following seasonal climatic events (rainfall, vertical mixing) that bring plant nutrients to the photic zone. Thus, organic matter in the diet increased four-fold, from 150 to 600 mg g^{-1} of diet. Protein content increased from 71 to 256 mg g^{-1} ash free dry weight (AFDW). Assimilation efficiency increased from 8.3% to 43.2% for AFDW, and from near 0 to 45.8% for protein. The fraction of organic matter that is refractory declined from 800 to 27 mg g^{-1} AFDW. Condition factor followed the same pattern, but lagged 1 to 2 months behind changes in diet quality. It was concluded that seasonal pattern of rainfall and temperature affect pelagic food resources, hence heterogeneity in diet quality is temporal to a great extent for *O. niloticus* in Lake Tana.

Key word/phrases: Assimilation efficiency, condition factor, food quality, Lake Tana, protein-energy ratio

INTRODUCTION

Like temperate environment, most tropical environments are highly seasonal. Rainfall is a major seasonal phenomenon that affects terrestrial and aquatic ecosystems (Wetzel, 1983). Light and temperature fluctuation also bring about significant influences (Wood *et al.*, 1976; Talling, 1986). In the Ethiopian highlands, total monthly rainfall averages from 0 to 40 cm and minimum monthly temperature ranges from 8 to 15° C. Rainfall and temperature are expected to profoundly affect primary production and the quality of food available for animals feeding at the base of the food chain. One such animal is the Nile tilapia, *Oreochromis niloticus*, a fish of the herbivorous tilapia group, which is abundant in Ethiopian lakes (Eyualem Abebe and Getachew Teferra, 1992). The natural distribution of *O. niloticus* extends throughout sub-Saharan Africa, but it has now been widely distributed through the warm regions of the world especially for use in intensive aquaculture. In the work reported here, we examined diet, assimilation efficiency and condition factor of *O. niloticus* in Lake Tana, Ethiopia, over a period of 13 months. In general, we are interested to find the extent of seasonal effects on the diet quality of *O. niloticus* in Lake Tana.

STUDY AREA

Lake Tana (12° 30' N, 37° 30' E) is Ethiopia's largest lake with a surface area of about 3150 km^2, and an average depth of 8 m and a maximum depth of 14 m (Rzoska, 1976). The lake surface is 1786 m above sea level. Lake Tana was formed by damming Gilgel-Abay river during late Pliocene or early Pleistocene (Mohr, 1966), and is the source of the Blue Nile. Lake Tana is an oligo-mesotrophic lake with an extensive macrophyte development (Rzoska, 1976) including *Cyperus, Scripus, Paspalidium, Phragmites, Ceratophylum* and *Nymphea* (Zenebe Tadesse, 1997).

The fish fauna of Lake Tana is relatively poor (Nagelkerke *et al.*, 1994). The Cyprinidae are represented by three genera: *Varicorhinus* Ruppel (1837), *Gara* Hamilton (1922) and *Barbus* Cuvier and Cloquet (1816). It is believed that the lake contains about 14 barbus-morphotypes including *Barbus intermedius* (Nagelkerke *et al.*, 1994). Some of these are now described as new species (Nagelkerke and Sibbing, in press). Other relatively abundant species are *Clarias gariepinus* Burchell (1822) and *O. niloticus* Linnaeus (1766).

MATERIALS AND METHODS

Fish were collected during day light hours with bottom trawl net, code end mesh size of 40 mm, from March 1992 through March 1993. Ten specimens were chosen arbitrarily from each catch. If fewer than ten fish were caught, all were retained for examination. Total length and fresh weight were recorded. Stomach contents and the contents of the last few cm of the digestive tract were separately removed and dried at 100° C. Dry samples were ground to pass through a 600 μm mesh, and stored in glass vials under refrigeration pending analyses.

Organic matter was determined as ash-free-dry-weight (AFDW) by weight loss on ignition at 550° C for 30 min. Total amino acid was determined in duplicate with alkaline hydrolysis followed by ninhydrin detection (Colowick and Kaplan, 1957). Energy content was measured by burning 10 mg samples in a Phillipson-type microbomb calorimeter (Phillipson, 1964). Samples low in organic matter often did not burn. To increase the probability of ignition, we added 1 μl oil to the pellet where it touched the ignition wire, and subtracted the energy content of this from the total measured energy to estimate the energy in the sample, *per se*. Hydrolysis resistant organic matter (HROM), a measure of cellulose, lignin and other refractory materials, was estimated as described by Buddington (1980) with a substitution of toluene for benzene in the series of solvent washings (S. H. Bowen, personal communication).

Assimilation efficiency (AE) is defined as the percentage of a nutrient ingested that is digested and assimilated through the gut wall. We calculated AE for organic matter and amino acids by ash-ratio method of Conover (1966), *i.e.*,

$$AE\ (\%) = (S-H)/S \times 100$$

where S is nutrient (mg mg^{-1} ash) in the stomach and H is nutrient (mg mg^{-1} Ash) in hindgut.

Condition Factor (CF) is a measure of plumpness, and in wild populations generally reflects nutritional status. We calculated condition factor as:

$$CF = W/L^3 \times 100$$

where W is live weight in g and L is total length in cm.

Rainfall and air-temperature were obtained from the National Meteorological Services Agency, Addis Ababa, Ethiopia. These measurements were taken at the southern shore of Lake Tana.

RESULTS

The two physical factors (rainfall and air-temperature) showed considerable variations. Rainfall was high from June to September and was low from November to March. Minimum air temperature was particularly low in December and January (Fig. 1a). The proportion of the organic fraction that was protein ranged from 71 to 265 mg g^{-1} AFDW, and was highly correlated with total organic matter (Fig. 1b and 1c, Pearson Correlation = 0.894, $p < 0.001$, $n = 13$). The protein components of the diet at the beginning of the rainy season and during the colder months, particularly in January were assimilated more than that in the dry season, with a high value of about 50% and a low value ranging from 0 to 20%. However, there was no significant correlation between the amount of protein and assimilation of protein (Fig. 1b; Pearson Correlation = 0.26, $p = 0.08$). We calculated negative assimilation efficiency for protein during March and May 1992 but for convenience they were taken as zero. The amount of refractory material (HROM) in the organic fraction showed inverse relationship with the amount of organic matter and protein (Fig. 1b and 1c).

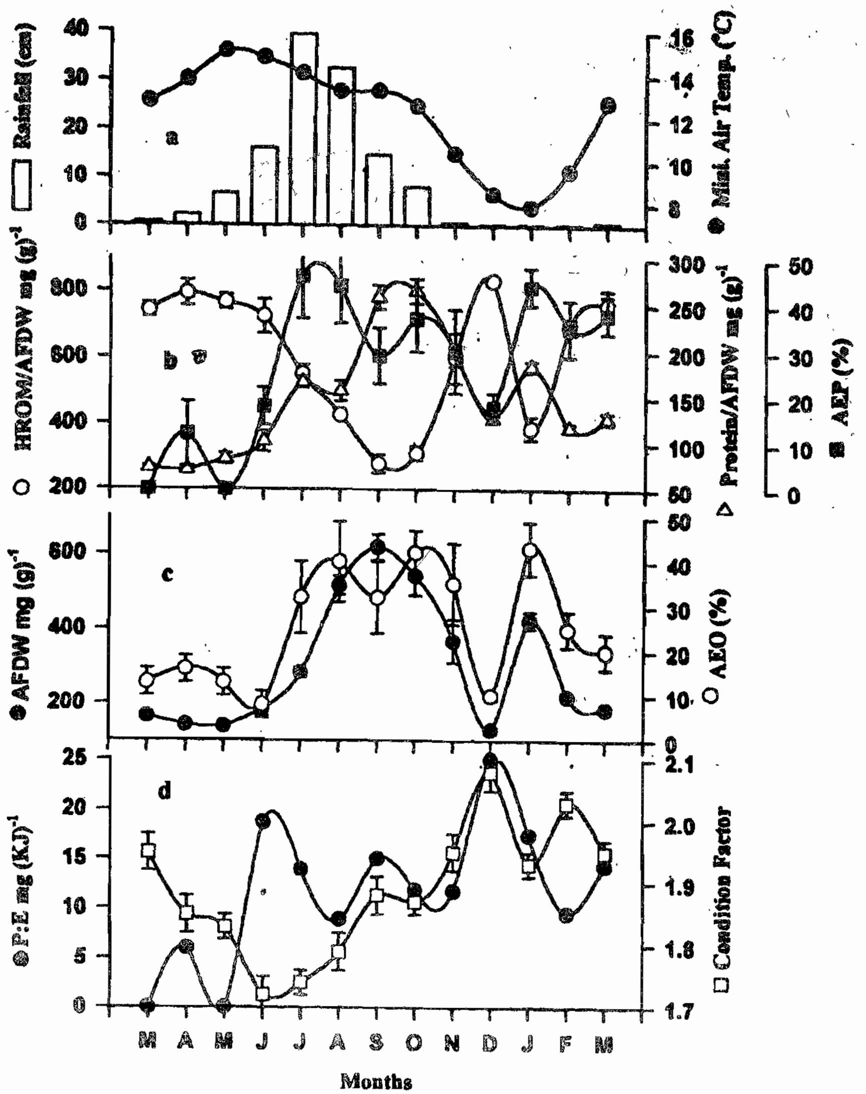

Fig. 1. **Seasonal changes in diet composition compared to rainfall and air temperature Points are means; error bars showed standard error.** (a) Monthly rainfall and minimum air temperature (b) Hydrolysis-resistant-organic-matter, and protein in stomach contents compared to assimilation efficiency of protein (c) Ash-free-dry-weight (AFDW) in stomach contents compared to its assimilation efficiency (d) A measure of food quality (protein-energy ratio) compared to condition factor.

Diet organic matter (AFDW) varied from 150 to 600 mg g^{-1} dry weight with two distinct peaks. A broad peak (August through November) followed the heavy rains in July, and a sharper peak in January coincided with the lowest monthly minimum air temperature. Assimilation Efficiency of organic matter (AEO) was generally positively correlated with the level of organic matter (Fig. 1c; Pearson Correlation =0.72, P<0.001). Samples with <20% AFDW gave incomplete combustion in the calorimeter. Thus, a regression line fitted to the set of all samples >20% AFDW was used to estimate the energy content of the stomach and hindgut samples from their AFDW content (KJ/g AFDW = 5.11 + (0.165*sample AFDW), adj. R^2 = 0.60, $p < 0.001$, n = 65 (Fig. 2). These energy values were used for subsequent calculation of protein-energy ratios.

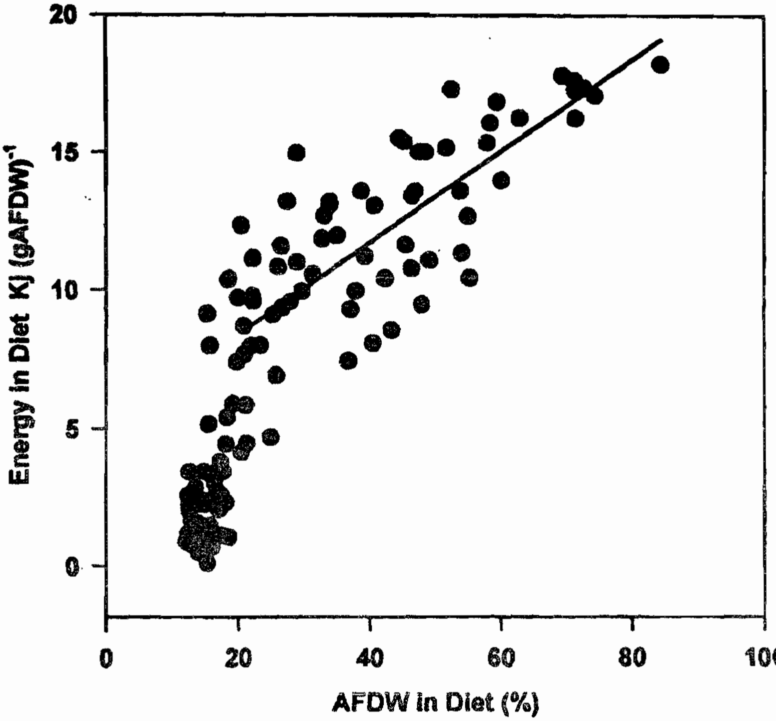

Fig. 2. Energy content of diet measured using a microbomb calorimeter. Many samples containing < 20% AFDW appear not to have burned completely, yielding improbable estimates < 5 KJ/g AFDW. Thus, the regression line fitted to estimate for all samples with AFDW > 20% was used to estimate energy content of the diet from diet AFDW.

The quality of the diet, *i.e.*, the ratio of assimilated protein to assimilated energy, peaked in June and July prior to the large increase in diet AFDW and peaked again in December when AFDW dropped to its lowest value. Changes in condition factor were correlated with the levels of protein-energy ratio but lagged by 1 to 2 months behind changes in diet quality, (Fig. 1d). As there was no significant difference between male and female condition factors, the mean condition factor is shown in Figure 1d.

DISCUSSION

O. niloticus is described as a microphagous species, feeding on seston either from suspension or from water-sediment interface (Fryer and Iles, 1972). In Lake Tana, the availability of phytoplankton varies with seasonal cycles (Zenebe Tadesse, 1997). During the warm, dry months of March through June, 1992, Lake Tana water was clear and the diet of *O. niloticus* was red in colour, from red clay in the sediment. A small amount of sand was also found in these samples. The low level of organic matter and protein, the low digestibility of the diet, and the high proportion of organic matter that is refractory (HROM) are all consistent with the conclusion that these fish were feeding on the sedimented organic matter. Most of this organic matter could be produced considerably earlier and had undergone significant degradation (Bowen, 1987).

Towards the end of the rainy season in August 1992, a conspicuous phytoplankton bloom developed, presumably stimulated by nutrients carried by streams to the lake (Zenebe Tadesse, 1997). Stomach contents from August through November 1992 were light brown in colour. The high level of organic matter and protein, the high assimilation of the diet and the low level of refractory organic matter (HROM) are all consistent with the conclusion that recently produced phytoplankton from suspension was the primary food during this period. The return to feeding on sedimented material in December likely reflects a decline of the phytoplankton population and accumulation of senescent cells on the bottom. Feeding during this time could be mainly on sedimented materials at the bottom of the lake, as the fish particularly males spend more time in nest building and courtship at this time of the year (Zenebe Tadesse, 1997). The female also visits this site regularly during breeding. We believe the second peak in January reflects a plankton bloom stimulated by hypolimnetic nutrients mixed into surface waters as a result of surface cooling. Although we do not have water-column thermal profile data for Lake Tana, thermal destratification due to surface cooling in December and January was found for nearby Lake Hayq (Elizabeth Kebede *et al.*, 1992). In general, this type of mixing is common in shallow tropical lakes like Lake Tana (Baxter *et al.*, 1965).

The ability of the fish to digest and assimilate organic matter correlates well with the amount of organic matter present in the diet, but there is no significant correlation between levels of protein and assimilation of protein. For example, during the rainy season and when it was cold the level of protein was low (about 180 mg g^{-1} AFDW) but assimilation efficiency was high (50%) (Fig. 1b). It appears that at the beginning of the rainy season, and when atmospheric air drops in January, some materials are produced that are more susceptible to digestion. Dissolved organic acids including free amino acids can be released form decomposing plant parts at the beginning of the rainy season. In January when the atmospheric air drops, the lake water mixes and organic nutrients in the bottom of the lake can be re-suspended into the water column. These molecules can be immobilized by diffusion into algal and bacterial cells (Fiebig and Marxen, 1992) or adsorbed on to particles (Aoyama and Nozawa, 1993; Diab *et al.*, 1993; Lowengart *et al.*, 1993). This could be a very rich source of protein that can easily be assimilated when ingested by the fish.

The seasonal changes in quality of diet reflect changes in condition factor. During the dry season, March through May, the diet was low in both protein and organic matter or energy, and condition declined steadily. At the beginning of the rains (June) and afterwards, the protein-energy ratio increased due to increase in the growth of phytoplankton, mainly blue greens, as the lake water became enriched with nutrients brought in by the rains. The increase in condition, however, lags about 1 to 2 months behind the changes in diet quality. In December the digestible organic content of the diet was low but this was mostly protein. The condition of the fish, however, remained high despite a low level of digestible organic matter or energy. We believe deterioration in the quality of the diet for a short period will not be immediately reflected by a decrease in the condition of the fish.

Seasonal data are also available for *O. niloticus* in Lake Ziway, Ethiopia (Eyualem Abebe and Getachew Teferra, 1992). Ziway is located between 7° 52' to 8° 8'N and 38° 44' to 38° 55' E at an altitude of 1636 m. Lake Ziway is also a relatively shallow lake with a maximum depth of 12 m. The basin of Lake Ziway includes large areas of deforested volcanic soils. During the rains, affluent rivers carry both nutrients and suspended particulate matter into Lake Ziway with the result that primary production is light limited for much of the year (Eyualem Abebe and Getachew Teferra, 1992). In both Lakes Ziway and Tana, *O. niloticus* feeds on mixtures of fine particulate matter. The nutritional value of the diet for supporting growth is affected by physical processes in the environment that determine the relative abundance of phytoplankton, organic detritus and mineral matter in the mixture. Phytoplankton have high nutritional value (Bowen *et al.*, 1995) and are more abundant in the diet of *O. niloticus* than most other tilapias (Moriarty *et al.*, 1973). The nutritional value of detritus is variable but generally it is lower than that of other organic materials, and mineral matter has no significant value as a source of major nutrients for animal growth. Thus, a process such as sedimentation (accumulation of senescent and degraded cells on the bottom) removes organic nutrients from the water column in Lake Tana and makes it less available to consumers. In another situation, mixing of organic nutrients with mineral-laden water from affluent rivers as in Lake Ziway dilute nutritionally valuable components on a scale that makes them less accessible to fishes. In Lakes Tana and Ziway, seasonal patterns affect pelagic food sources and hence heterogeneity in diet quality is temporal to a great extent.

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