SEASONAL CHANGES IN THE NUTRITION OF *Oreochromis niloticus* Linn. (Pisces:Cichlidae) IN LAKE ZIWAY, ETHIOPIA

A THESIS PRESENTED TO
THE SCHOOL OF GRADUATE STUDIES
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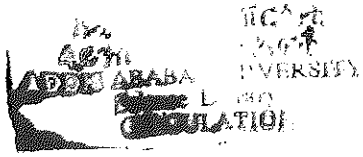

IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE
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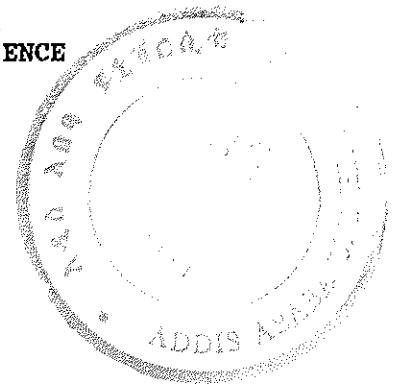

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ABSTRACT

The quality and digestibility of the natural food of Oreochromis niloticus in Lake Ziway, Ethiopia, was studied for a period of one year, October, 1988 to September, 1989. The stomach and rectal contents of 956 fishes were analyzed for total organic matter, protein, lipid, carbohydrate and energy. Different forms of inorganic nitrogen and ortho-phosphate in the water were also determined to assess if there is any relationship with the composition of the diet.

Total organic matter (55.7% D.W.), protein (4.6% D.W.), lipid (5.3% D.W.) and energy (8.7KJ/g D.W.) were consistently low for most parts of the year, while carbohydrate (21.5% D.W.) was relatively high. Protein, lipid and carbohydrate accounted for 57.0% of the ash free dry weight (AFDW). Detritus is assumed to contribute most of the unaccountable portion of the AFDW. All nutrients showed significant monthly variation (ANOVA, $P < 0.0001$), however, the variation of nutrients between sexes was not significant (ANOVA, $P > 0.05$).

Estimates of assimilation efficiency using ash as a reference marker revealed that 36.7% of the total organic matter was absorbed. Protein, lipid, carbohydrate and energy had digestibility values of 73.3%, 13.3%, 39.1% and 37.3%, respectively. Assimilation efficiency values were also estimated for three months using three indigenous markers, ash, hydrolysis resistant ash (HRA), and hydrolysis resistant organic matter (HROM). Results showed that ash and HRA gave higher values in two (August and November) of the three months considered. HROM gave higher values only in one month (May).

The quality of food expressed as the ratio of digestible protein to Kilo Joule of digestible energy varied significantly over the 12 months considered, and ranged from 6.0 to 117.0. Although the quality of the food appears to be sufficient to support growth during most of the year, low amount of digestible organic matter in the diet seems to restrain the maximum growth possible. Condition of O. niloticus was variable between months but not between sexes. Monthly food quality and the corresponding condition of fish had no significant correlation ($r = 0.012$) indicating that fish condition might not be sensitive enough to detect changes in food quality over a short period of

time. The overall condition of O. niloticus in Lake Ziway was found to be lower than that of Lake Awassa, and this is probably due to inferior quality of the diet and lower feeding rate.

The length-weight relationships of O. niloticus that range from 11.2 to 31.0 cm in size were found to be, $W = 0.028\ L^{2.874}$, $r^2 = 0.906$, $P < 0.0001$ for males and $W = 0.106\ L^{2.448}$, $r^2 = 0.852$, $P < 0.0001$ for the females.

There was no relationship between the composition of the diet of O. niloticus of Lake Ziway and the nutrients (nitrogen and phosphorus) in the lake water.

I- INTRODUCTION

Primary food sources in the aquatic environment include vascular plants, macroscopic and microscopic attached algae, phytoplankton and organic detritus derived from living plants (Bowen, in press). Man can make very little use of aquatic plants as food and hence most of these plant materials are not edible to humans (Idyll, 1970). Moreover, harvesting even the so called edible algae has been a very difficult problem (Edwards, 1980).

When food passes from one trophic level to the next higher trophic level, there is a loss of substance and energy which amounts to about 80 to 90% (Marshall, 1965; Odum, 1971). This, in light of the present protein shortage, is undesirable. Thus, it is self evident that attention should be drawn to animals that effectively use primary food resources and which are in turn readily available for human consumption. These apart from invertebrates, include herbivorous and detritivorous fishes. Fishes, that feed on primary food resources, are relatively few in species, but have achieved wide distribution and various reports show their disproportional success in ichthyomass, mainly in the tropics, (Dunn, 1972 cited in Moriarty, 1973; Lowe-McConnell, 1975; Schroder, 1984; Bowen, 1988). With this in mind Tilapiine fishes have been the preferred choice for fisheries development in different parts of the world.

The group of fish species commonly known as tilapia (which recently is sub-divided into four genera, Trewavas, 1982) is endemic to Africa but the various species are now found in most tropical and sub tropical areas of the world. Oreochromis niloticus, a member of the group, is also widely distributed in fresh waters of Middle East, eastern, central and western Africa (Balarin and Hatton, 1979). Its expansion is still going on (Philipart and Ruwet, 1982). Apart from playing important role in African fisheries O. niloticus is one of the ten most popular cultured species (Balarin and Hatton, 1979).

Tilapias have an extraordinary tolerance to varied ranges of physical conditions, depth, current velocity, turbidity, temperature and chemical composition, especially salinity, pH, dissolved oxygen and other gases of the water bodies in which they live (Balarin and Hatton, 1979; Cherviniski, 1982;

Philipart and Ruwet, 1982).

Although Tilapiine fishes in general are herbivores (Fryer and Iles,1972), detritivore species are also present (Bowen, 1979; 1980; 1982; 1983). In addition, some species show opportunistic nature and display shifting ability from one feeding habit to the other (Maitipe and De Silva, 1985).

Pond experiments (McBay, 1961) as well as studies done in natural environments (McBay, 1961; Fryer and Iles, 1972; Moriarty, 1973; Moriarty and Moriarty, 1973a; 1973b; Getachew, 1987; Zenebe, 1988) show that the adult O. niloticus feeds mainly on phytoplankton and occasionally some detritus. Foods of animal origin are reported to be consumed by adult fish in addition to phytoplankton (McBay, 1961; Moriarty and Moriarty, 1973b; Zenebe, 1988). Food selection is also reported for the same species by Moriarty et al. (1973).

Fry and juvenile stages of O. niloticus, as other Tilapiine fishes, feed on animal matter mainly zooplankton (McBay, 1961; Moriarty, 1973; Moriarty and Moriarty, 1973b; Balarine and Hatton, 1979; Bowen, 1982; Zenebe, 1988).

Some workers (Stickney and Shumway, 1974; Buddington, 1980) have shown that fish are among those vertebrates that lack cellulase secretion in their digestive system. Prejs and Blaszczyk (1977) reported cellulase activity from fish and indicated the presence of some amount of highly processed plant detritus in guts even though the enzyme itself was not isolated. The presence of cellulase activity in fishes is therefore doubtful in that the cellulase activity observed might have come from the microbial population ingested with the detritus. Therefore, it is possible to generalize that fish cannot digest cellulose and lignin which are major components of plant cell wall. In addition, Fish (1955) reported that whenever plant cells are undamaged, there would be no digestion of the contents of the plant material. Although previous studies (Lobel, 1981) failed to show the presence of cellulase producing gut flora in fishes, in a recent report Rimmer and Wiebe (1987), have demonstrated their presence in two herbivorous fish species. Nonetheless, the success of primary consumer fishes is the result of complex anatomical, physiological and behavioral adaptations that have enabled them to solve the inherent problems associated with primary food resources(Bowen, 1988).

Among the various earlier suggestions of how Tilapia spp (mainly herbivores) may digest blue green algae, Fryer and Iles (1972) proposed that the high sodium to calcium ratio of salts dissolved in the waters of alkaline lakes of East Africa (from which they collected the fishes) may be partially responsible. Other more important physiological and anatomical adaptation have later been elucidated (Moriarty, 1973; Bowen, 1976) and it is now well known that acid secretion in the stomach lyses bacteria and algal cells.

Fish (1960) was the first person to suggest that gastric pH might secondarily function to lyse algal cell walls and allow digestion of plants. Later Moriarty (1973) reported the lysis of blue-green algae in an acidic medium and in the stomach (pH = 1.40) of O. niloticus. Bowen (1976) also reported that Oreochromis mossambicus uses the same mechanism to digest bacteria associated with detritus in its diet. Short term exposure at pH 2.00, 2.50, 3.00 and extended exposure at pH 3.50 is able to lyse algal cells (Lobel, 1981). A difference in sensitivity of algal species to acidic lysis was also reported by the same worker. Here the nature of the cell wall appears to be important, for instance the cell wall of green algae is resistant to lysis than the cell wall of the blue-greens (Moriarty,1973).

Absence of enzyme activity with a pH value of 1.75 was observed by Bowen (1976) from the stomach of O. mossambicus. In addition to its lysing purpose gastric acidification in this fish species liberates complexed amino acids in detrital aggregate. Unusually low pH also fundamentally alters the chemical structure of detritus in ways that may facilitate intestinal digestion (Bowen, 1981).

Digestibility refers to the percentage of nutrient that is available to fish (Buddington, 1979). When the digestibility of primary food resources is considered it is generally lower than that of animal tissue (Kirilenko et al., 1975; De Silva and Perera, 1983). The low digestibility of plants is attributed to the preponderance of complex structural carbohydrates (Boyd and Goodyear, 1971). When the digestibility of protein is specifically considered fish can digest animal tissue protein at levels greater than 90% (Beamish, 1972 cited in Buddington, 1979), but plant tissue protein are less (40 to 80%) digestible (Gerking, 1952 cited in Montgomery and Gerking, 1980; Kirilenko et al., 1975). Furthermore excessive amount of inorganic material taken with the

food reduces efficiency of digestion in filter feeders and detritivores (Bowen, 1981).

The ingestion of large quantity of food at minimal cost (time or energy) is important in higher trophic levels, although this does not hold true in primary consumers. The food of primary consumers is generally present far in excess of their ability to consume it (Moriarty et al., 1973). This is especially true in the tropics where there is high rate of primary production continuously throughout the year. Nevertheless food (nutritive) quality is extremely variable and plays a major role in governing secondary production (Boyd, 1970; Boyd and Goodyear, 1971; Bowen, 1982; 1988).

The quality of a given diet is directly proportional to its ability to support growth. It depends on the composition of the diet and the extent to which the components are digested and assimilated (Bowen, 1982).

A proper balance between protein (growth food) and carbohydrate and fat (energy foods) is needed by fishes for basic anabolic activity, which in addition to growth includes tissue repair, reproduction and the production of essential body products. Vitamins and minerals, although required in very small amounts, are essential for proper functioning of the body of fishes (Phillips, 1969).

In the natural environment, only one nutrient has been identified as a frequent and wide spread limiting factor to primary consumer growth, and that is protein (Boyd and Goodyear, 1971; Mattson, 1980). The acquisition of sufficient protein in the diet will likely insure that a herbivore obtains adequate quantities of other nutrients (Boyd and Goodyear, 1971). The diets of tilapias range from about 50% to less than 1% protein (Bowen, 1982).

Nutritional value of a given diet may be expressed in terms of (KJ) digestible energy/g, and benefit to the consumer may be expressed as an energy assimilation rate (Bowen, 1987). However, despite wide variations in composition of different materials, amounts of chemical constituents of differing caloric value approach a relatively constant ratio so that most plant materials have a caloric content around 16.74 to 17.57 KJ/g dry weight. Moreover since only energy in the form of digestible nutrients is available to herbivores, caloric analyses of vegetation (plant matter) have little significance in indicating food quality (Boyd and Goodyear, 1971).

Another concept is based on amino acid or protein content. The interaction between amino acid concentration and energy assimilation rate is very essential because dietary amino acids provide the material for animal growth and dietary energy carries out the actual growth process (Bowen and Ahlgren, unpublished). Clearly this shows that either dietary energy or amino acids can potentially limit growth (Bowen, 1987). Therefore, to describe food quality, protein levels are frequently expressed as mg assimilable protein per KJ assimilable food energy. A minimum of 4 mg protein per KJ was found to be required for maintenance by O.mossambicus (Bowen, 1982). Growth increased with increasing protein levels up to a maximum of about 25 mg protein per KJ (Bowen, 1982), showing the presence of some stage in process at which the energy-amino acid balance has maximum nutritional value (Bowen, 1987). Protein at higher levels is in excess of the animals ability to utilize it anabolically and thus growth decreases presumably as a result of energetic cost of protein catabolism (Boyd and Goodyear, 1971; Bowen, 1982).

This ratio, mg assimilable protein/KJ assimilable energy, has been used by several workers (Bowen, 1979, 1980; De Silva, 1985; Getachew, 1989) to assess food quality of fishes under natural conditions.

The nutritional benefit from any food is ultimately its contribution to the consumer's fitness. However, since fitness is difficult to measure directly, a variable that is proportional to fitness is often measured instead. Growth of fishes can be considered a close approximation of fitness (Bowen, 1988). Condition factor, another indirect measure of fitness, can also give some indication of nutritional benefit (De Silva, 1985; Getachew, 1987).

Although seasonal changes in day length and temperature are small in the tropics compared with those in temperate regions, seasonal changes in wind and rainfall regimes do cause some seasonality in most tropical ecosystems (Lowe-McConnell, 1987). Therefore qualitative and qauntitative changes in available food of fish, quality being more important to herbivores, are brought about by rainfall and wind regimes in tropical lakes.

Studies done on some of the Ethiopian rift valley lakes, like Lake Awassa (Demeke, 1985; Elizabeth, 1987), Lakes Langano and Abijata (Kassahun, 1982), Lake Ziway (Tsegaye, 1988; Girma, 1988; Semeneh, 1988) show that there

is a marked difference between the rainy and dry seasons with respect to nutrient concentrations, phytoplankton primary production, abundance and composition of the plankton and other physical and chemical factors. Primary production differs in chemical composition and nutritional value depending upon the species, age and habitat of the producer (Boyd, 1970; Boyd and Goodyear,1971). Even for an individual algal species the biochemical composition of algal cells depends to a large extent on changing environmental factors such as light, temperature and nutrients (Gibson, 1978; Olesen and Ganf, 1986; Amblard and Bourdier, 1988). Therefore a year round study and seasonal consideration of food quality for an herbivorous fish species in a specific environmental set-up is a logical approach to the understanding of the species' nutritional status in that specific habitat. Such studies have not been adequately made for the tropical fish at large and the herbivorous fish species of the Ethiopian rift in particular. The only seasonal study done in this country was by Getachew (1987) on O. niloticus in Lake Awassa. His study revealed the seasonal nature of food quality and fish condition. Differences in condition between sexes, at least for some months, were also detected.

Inexpensive source of protein is needed to support the ever increasing human population especially in a country like Ethiopia where there is a serious protein deficiency. The aquatic resources of Ethiopia are not fully exploited and therefore their effective utilization calls for special attention. The sustainable utilization of these resources requires proper management which in turn needs thorough understanding of the systems.

Apart from being one of the most commercially important fishes in Ethiopian fisheries, O. niloticus dominates (94%) the fish community of Lake Ziway (Schroder, 1984). The annual fish yield from Lake Ziway is estimated to be 1000 tons (Schroder, 1984). Although some studies have been made on some aspects of the biology of O. niloticus; breeding period and fecundity (Getaneh and Getaneh, 1979; Zenebe, 1988), feeding periodicity and length-weight relationship (Zenebe, 1988), information on the nutritional status of this fish species in this lake is still lacking. Therefore, this study is an attempt to:-

II - THE STUDY AREA

The Ethiopian rift system is characterized by several internal drainage basins with lakes (Mohr, 1962). The Ziway-Shalla basin is the northerly of the three basins in this rift system. Lake Ziway is the most northerly of the four interconnected rift valley lakes, Ziway, Abijata, Langano and Shalla (Fig. 1), that form the Ziway-shalla basin (Von Damm and Edmond, 1984). The lake's western and eastern parts lie in the South-Shewa and Arsi administrative regions, respectively, while its northern shore borders East-Shewa administrative region. It is located at ca 7° 52' N - 8° 8' N latitude and ca 38° 55' E longitude (Fig. 2), 150 Km south of Addis Ababa (Makin et al., 1975). The morphometry, and monthly rainfall and wind speed of Lake Ziway are given in tables 1-A and 1-B, respectively.

Lake Ziway lies in an altitude of 1636 m within a broad down faulted basin formed through local subsidence of the rift valley floor. To the north, the land rises gently, and to the south of the lake the landscape is dominated by Mount Alutu, a major center of Quaternary silicic volcanism (Makin et al., 1975). The lake contains five main islands (Galila, Tulu-Gudo, Funduro, Tedecha and Debresina Mariam), which are of volcanic origin (Schroder, 1984).

The climate in the basin has arid characteristics for most of the year, the highest temperatures occur between March and June prior to the start of the main rains, though seasonal variation in daily temperature is relatively slight. The windiest periods are November to January, and immediately preceding the main rains in June (Makin et al., 1975). The weather is frequently windy and stormy (Schroder, 1984). These local meteorological conditions cause frequent mixing of the lake throughout the year (Girma, 1988).

Reports show that the mean annual rain fall is generally less than 600 mm (Grove et al., 1975; Makin et al., 1975). The area is characterized by two rainy seasons, February - April and June - september. The small rains are in February and June, the big rains from June to september. High concentration of rain fall occurs in July and August (Daniel, 1977).

The lake is fed by two major rivers, Meki and Katar, which drain from the Western and South-Eastern plateau, respectively. The Meki river drains an

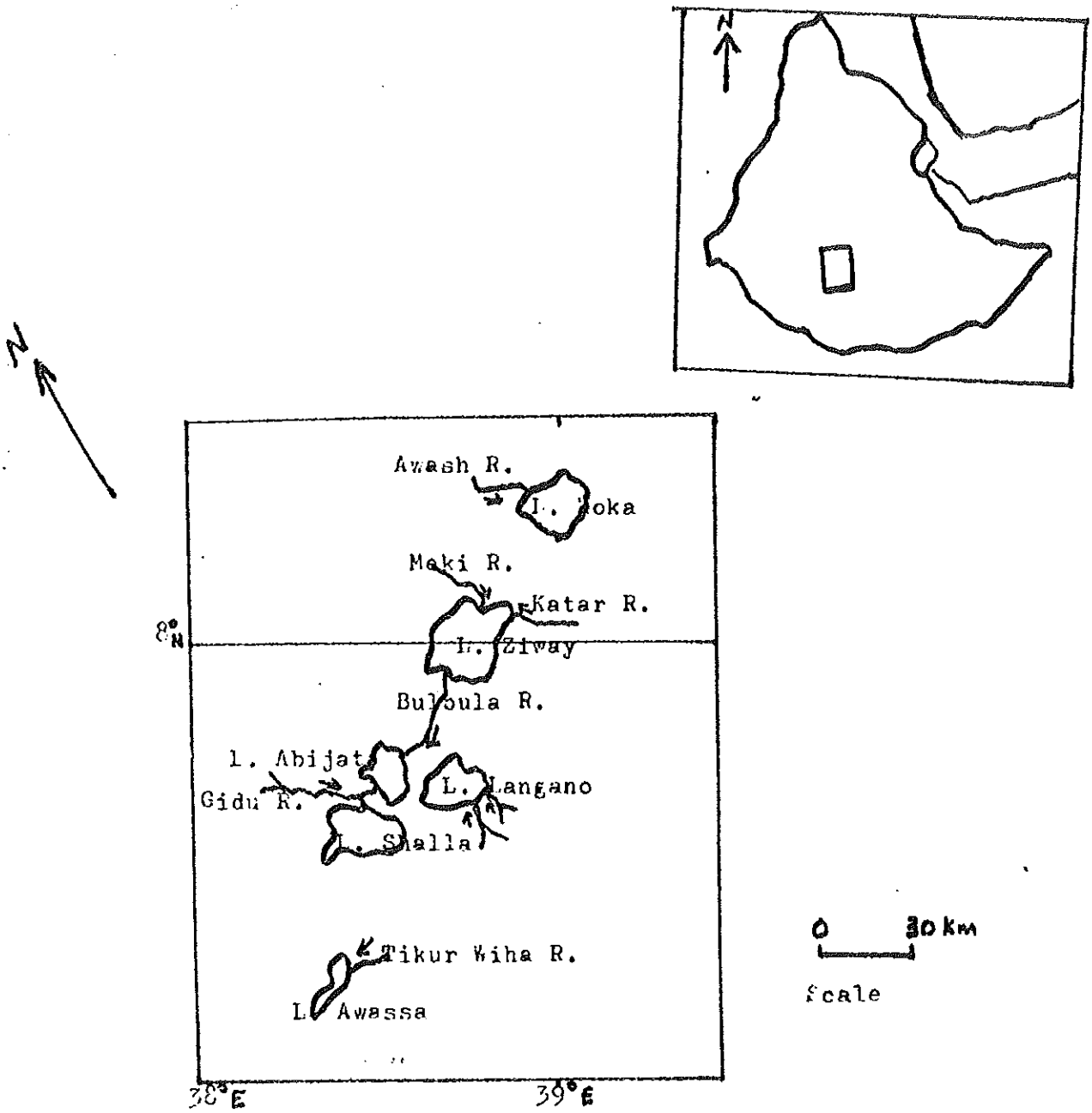


Fig. 1. A map showing some of the rift-valley lakes of Ethiopia.

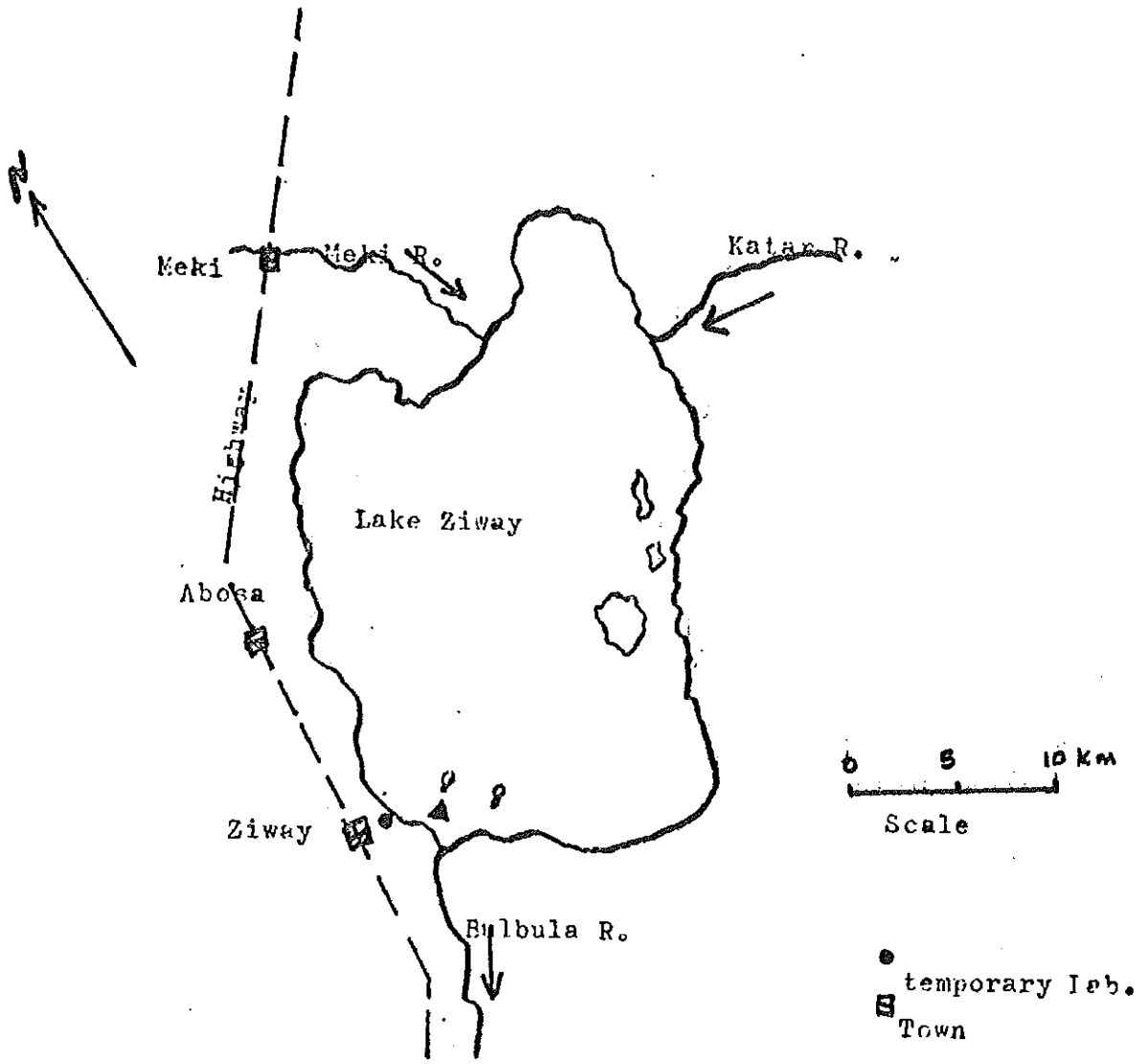


Fig. 2. Map of Lake Ziway showing the sampling station(Δ)

Table 1-A. Morphometry of lake Ziway.

CHARACTER	VALUE	REFERENCE
Area of lake surface	434 Km^2	Schroder, 1984.
Maximum extensions	32 by 20 Km	Schroder, 1984.
Maximum depth	12m, mostly around 6m	Schroder, 1984.
Mean depth	2.5 m	Schroder, 1984.
Volume of water mass	1.1 x 10^9 m^3	Schroder, 1984.
Water renewal time	3.2 yrs.	Schroder, 1984.
Area of water shed	7025 Km^2	Haberland, 1963.
Shoreline	102 Km	Schroder, 1984.

Table 1-B. Monthly rain fall (mm) and average monthly wind speed (m/s) of the lake region (Ziway Station - 1988/1989). From National Meteorological Services Agency.

MONTH	RAIN FALL	WIND SPEED
October	99.4	1.5
November	0.0	1.8
December	0.2	2.1
January	4.7	2.1
February	50.3	2.1
March	195.7	1.7
April	129.9	1.4
May	2.9	2.0
June	101.9	2.7
July	120.0	2.8
August	150.5	2.1
September	133.1	1.5

area of ca 2300 Km^2 while the Katar river drains a larger catchment of ca 3400Km^2 (Makin et al., 1975). The average discharges from the two rivers are estimated as ca 420 x 10^6 and 437 x 10^6 m^3 of water per year (Von Damm and Edmond, 1984). In addition to the two rivers, Meki and Katar, lake Ziway has also its own catchment covering about 1700 Km^2 (Makin et al., 1975). Several mineralized springs around the lake shore that contribute a significant ground water also flow towards the lake (Makin et al., 1975; Schroder, 1984). Including the rainfall, Lake Ziway receives ca 1150 x 10^6 m^3 of water annually (Makin et al., 1975). The lake drains south from its South-West corner via the Bulbula river into Lake Abijata. The Bulbula river has a discharge of ca 211 x 10^6 m^3 of water per year. The difference between inflow and outflow amounting to an average of 940 x 10^6 m^3 of water per year is accounted for by evaporation from the lake surface (Makin et al., 1975).

Lake level is known to fluctuate from time to time depending on the climate (Grove et al., 1975; Makin et al., 1975). A more significant rate of change is expected when considering the newly started state farms in the area. Two small state farms have been using lake water for irrigation for the past 10 years. There is also a larger state farm that has recently started pumping water from the lake. This will have a tremendous effect on the water budget of the lake and will affect its biota.

Lake Ziway water is brownish or greenish, depending whether the suspended material is predominantly inorganic or organic (Wood et al., 1978).

Lake Ziway is bordered by swamp, except along the South - Eastern and Southern margins (Makin et al., 1975). The shores are sandy or rocky (schroder, 1984). A high portion of the lake bed is composed of coarse pumice material. Along the Eastern and Southern sides of the lake soils are coarse-textured with an organic loam top soil over pumice sand (Makin et al., 1975). The volumetrically important constituents of the deposits in the area are pumice, glass shards, volcanic rock fragments, feld spars and quartz. The important heavy minerals are pyroxene, hornblende, magnetite and biotite, indicating volcanic sources. The sediments contain organic matter in concentrated and dispersed form (ketema, 1986).

An almost continuous cultivation under an open canopy of remnant acacia, principally Acacia tortilis is characteristic of the area around the lake.

Maize is the most important crop in the area around the lake. During the wet season, it occupies 80% of the land surface (Makin et al., 1975).

The shore line is fringed by discontinuous blocks of typha (bull rush) and Cyperus papyrus. Beyond this, in the open water, there is almost continuous floating belt of phragmites (reed) with Nymphia (water lily). Along both sides of the bank of the Bulbula river, there is often a narrow thicket of leguminous shrub, Saschynomene elaphrxylon. Expanses of Cynodon plectostachyus grass land which provide valuable grazing when the lake is low and the unpalatable grass Sporobolus spicatus are also present although they are very localized (Makin et al., 1975).

A total of 122 phytoplankton species have been identified (Tsegaye, 1988) of which 50 species are blue-greens, 41 green algae and the rest 31 diatoms. Most important species in terms of biomass are Lyngbya limnetica, Microcystis aeruginosa and Synechococcus elongatus (blue-green algae), Melosira granulata, Navicula spp and Surirella spp (diatoms), and Straurastrum leptocladum and Pediastrum boryanum (green algae).

The zooplankton population is composed of five genera of crustacea and six genera of rotifers (Semeneh, 1988). Mesocyclops spp, Microcyclops spp and Afrocyclops spp are the cyclopoids. The two dominant cladoceran species are Diaphanosoma excisum and Alona davidii. Keratella spp, Brachionus spp, Filinia spp, Hexarthra spp, Lecane spp, and Trichocerca spp are the rotifers reported to exist in the lake.

The fish population in the lake is dominated (94%) by the herbivore Oreochromis niloticus. Other species in the lake are Barbus (6%) of unidentified species (Schroder, 1984) and Tilapia zilli, an introduced species from Uganda (George, 1976). In addition to these three fish species a different and probably an introduced one has been observed (pers. obs.) among the fishes caught for commercial purposes by fish production and marketing corporation Ziway-branch. According to local authorities of the ministry of agriculture the fish appears to be a carp.

The lake also supports a rich avian fauna among which are pelicans (Pelicanus oncocrotalus) and lesser flamingoes (Phoeniconaias minor). Other animals that are found in the lake include hippopotamuses (Hippopotamus amphibius), mammals, and the nile monitor.

III - MATERIALS AND METHODS

Fish were collected monthly from a sampling site (Fig. 2) for 12 months (October 1988 - September 1989). Gill nets (60, 80 and 100 mm mesh stretched) set overnight were used for the first four months while beach seine haul nets (80 mm mesh stretched) were used for the remaining eight months. Fish were alive when they reached the near-by temporary laboratory. Total length and weight were measured to the nearest 0.1 cm and 0.1 g, respectively and then the fish were dissected. The stomach and rectal contents were transferred into vials and allowed to dry at 100°C. The stomach contents were considered as food while rectal contents were considered to be the faeces. Since rectal contents were insufficient for all analyses, the stomach and rectal contents of five fish were separately pooled. The pooled stomach as well as rectal contents were ground using a mortar and pestle and sifted through a 650 um mesh size sieve. These sifted samples were analyzed for total organic matter, protein, lipid, carbohydrate and energy.

The protein content was determined by Lowry's method (Lowry et al., 1951) as modified by Kaushik and Hynes (1968). Stomach and rectal samples, 100 and 50 mg, respectively, were extracted in 10 ml of 0.1 N NaOH for 24 hours at room temperature in a mechanical shaker. The extract was separated by centrifugation from the remaining solid component. From the 10 ml extract only 5 ml was taken and to this 5 ml, 10 % trichloro acetic acid (TCA) was added and the mixture was kept overnight in a refrigerator at 5°C for complete precipitation of protein. The supernatant was then separated by centrifugation and decanted. The precipitate was redissolved in 2 ml of 0.1 N NaOH. Seven ml of dissolving reagent (50 ml of 2 % $NaCO_3$ in 0.1 N NaOH + 1 ml of 0.5 % $CuSO_4$. 5 H2O in 1 % Potassium tartrate) was added to the resuspended precipitate and mixed. Ten minutes later 1 ml of Folin's reagent was added with mixing. After 30 minutes the absorbance was read with a spectrophotometer (Spectronic 1001, Milton Roy Company) at 750 nm. Bovine serum albumin was used to construct the standard curve.

Lipid was determined as described in Golterman et al. (1978) and modified by Getachew (1987). Extraction was done in Soxhlet apparatus with diethyl ether for 3 hours from a known weight of sample (100 mg for stomach

and 50 mg for rectal samples) contained in folded and stapled glass filter paper (GF/C), which was previously ether extracted. The sample was then air dried for 10 minutes and oven dried at 100°C for 30 minutes and cooled in a desiccator. The filter paper with the sample was then weighed and the difference in weight taken as the weight of lipid.

Total carbohydrate was determined by the phenol-sulphuric acid reaction (Strickland and Parsons, 1968 as modified by Bowen, in Getachew, 1987). One ml of distilled water and 1 ml of 5% phenol was added to 10 mg of sample. After mixing, 5 ml of sulphuric acid reagent (0.5% hydrazine sulphate in sulphuric acid) was added from a rapid flow burette. Further mixing was carried out by shaking the flask during the addition of the acid. Then it was left for 1 hour to cool. A blank solution was prepared from distilled water, 5% phenol and sulphuric acid reagent with out sample added. From this blank solution 4.5 ml was taken in a centrifugation tube and to it 0.5 ml of the test solution added. This was mixed with a vortex mixer and then centrifuged for 10 minutes. Absorbance of test solution was read at 550 nm against a blank solution (distilled water, 5% phenol and sulphuric acid reagent with same proportion as test solution but lacking sample). Glucose was used to construct the standard curve.

Total organic matter was determined by igniting a known weight of sample. Hundred mg of sample was placed in a crucible and ignited in a muffle furnace (Fisher Isotemp Muffle Furnace 184 A) at 550°C for 4 hours. The weight loss after ignition was considered to be the weight of total organic matter (ash free dry weight, AFDW) in the sample, the remaining being the ash.

Total energy of the sample was determined using a Phillipson micro-bomb calorimeter model 435 (Gentle Ins. Inc.). Pelleted sample weighing 15 - 28 mg was put in the sample holder of the micro-bomb and a 3 cm long and 0.001 mm diameter platinum wire was stretched over it in such a way that ignition was insured by the slight contact made. A drop of water was added to the lower half of the bomb to create a saturated atmosphere. The micro-bomb was then flushed with oxygen (30 atmosphere) from a pressurized oxygen supply. It was then cooled by immersing it in cold water, dried and placed on the copper ring of the stand. The two ends of the firing circuit were connected to the bomb. To minimize the effect of the external environment it was covered by a

stainless steel jacket. The recording system (Can lab recorder model 255) was allowed to attain equilibrium and then the condenser was discharged and the sample ignited. After the heat rise in the bomb was recorded and cooling was apparent the operation was stopped. Benzoic acid with 99.9% purity and 6324 calories per gram calorific value was used to calibrate the bomb. A constant was determined which was later used to convert recordings into calories (Phillipson, 1964).

Ash was used consistently as an indigenous marker for the computation of assimilation efficiency. Two other indigenous markers, hydrolysis resistant organic matter (HROM) and hydrolysis resistant ash (HRA), were also determined for some months. HROM and HRA were determined by the method of Buddington (1980). Usually 200 mg sample was placed in a 50 ml beaker and 5 ml acetic acid (80%) was added and this was boiled for 20 min on a gentle flame. Then, 0.5 ml concentrated nitric acid and 70% ethanol were added, respectively and the content of the beaker was transferred to an alundum crucible. The beaker was repeatedly washed with ethanol from sqeez bottle to ensure complete transfer of the digested sample to the alundum crucible. The hydrolysed component was separated from the remaining hydrolysis resistant component (HROM and HRA) by putting the alundum crucible on the mouth of buchner flask which was attached to a vacuum pump through a tube. During this separation the sample was rinsed successively with hot alcohol and petroleum ether to remove remaining hydrolysed organic matter and inorganic minerals. The sample in the crucible was then dried at 100°C to be weighed after cooling in a desiccator. It was then ignited at 550°C for 4 hours. That part of the sample remaining in the crucible after ignition was HRA while weight difference between weights taken just before and after ignition gave the weight of HROM. Assimilation efficiency was determined using the equation given below (Conover, 1966).

$$A.E.(\%) = \frac{F/M - F'/M'}{F/M} \times 100$$

F = Nutrient in food F' = Nutrient in faeces

M = Marker in food M' = Marker in faeces

Condition factor of fish was calculated from total length and weight measurements. Fulton's as well as relative condition factor were calculated using the following equations (Le Cren, 1951; Anderson and Gutreuter, 1983).

$$\text{Fulton's condition factor (FCF)} = W/L^3 \times 100$$

Relative condition factor (RCF) = W/aL^b

where W = weight in grams

L = length in cm

a = Y-intercept; b = slope of the regression line, log L vs log W, for fish collected through out the study period.

The quality of the food for each month was determined by taking the ratio of digestible protein to digestible energy as an index. Digestible protein was determined by taking the product of protein in the food and the proportion of protein assimilated. Digestible energy was also taken as the product of the amount of energy in the food and the proportion of assimilable energy.

WATER SAMPLING AND NUTRIENT ANALYSES

Sub-surface water sample was collected from the study site using polyethylene bottles. The water sample was kept in a cooler filled with ice and transported to the laboratory in Addis Ababa. It was kept in a refrigerator for the night and the next day the water was filtered through Whatman GF/C glass filter. The filtered water was then analyzed for the following nutrients. Nitrite + nitrate-nitrogen, ammonia + ammonium-nitrogen and soluble reactive phosphorus (ortho-phosphate).

Nitrite + nitrate-nitrogen was determined as described in Golterman et al. (1978). Lake water, after passing through cadmium-copper column was diazotized with sulphanilamide and coupled with the aromatic amine N-1-Naphthylethylenediamine di-hydrochloride. Absorbance was read (Pye Unican sp-350) at 543 nm.

Ammonia + ammonium-nitrogen was determined by the phenol-nitroprusside method as outlined in Mackereth et al. (1978). Absorbance was read at 635 nm. Dissolved reactive phosphorus was estimated colorimetrically as its molybdate complex as described in Golterman et al. (1978). Absorbance was measured at 882 nm.

STATISTICAL ANALYSES

Analysis of variance (ANOVA) was used to test the differences between means and multiple comparison of means was done using the GT2 - and T - methods (Sokal and Rohlf, 1981). T - method was used only for the comparison of means of condition of fish.

IV - RESULTS

IV - 1 Nutrient composition

The total length of the 956 fish, 562 male and 394 female, which were collected during the sampling period was between 11.2 cm and 31.0 cm. Most (>65%) were in the size range of 20.0 - 25.0 cm.

Total organic matter (AFDW) in the food of O. niloticus in Lake Ziway was in the range of 33.9 to 74.4% dry weight (% D.W.) with a mean of 55.7 % (Fig. 3). There was a significant monthly variation in % AFDW (ANOVA, $P < 0.0001$) but no significant sex difference was observed. Organic matter was highest in December and there was a tendency to decline during the rainy season. The food ingested in October seems to contain the lowest organic matter (Appendix I - A).

The energy content of the food of O. niloticus in Lake Ziway varied greatly from month to month ($P < 0.0001$). The food of O. niloticus that had the lowest energy, 5.7 KJ/g dry weight, was that eaten during the month of October (Fig. 3). Most dry months (November, December and January) had significantly higher energy values (Appendix I - B), the highest being in December, 11.8 KJ/g dry weight. Total energy and AFDW in the food had very similar temporal (monthly) patterns. As in AFDW, energy had a tendency to decrease during the rainy season (Fig. 3).

The composition of the nutrients in the diet of O. niloticus was dominated by carbohydrate (Fig. 4). Carbohydrate in the food was high (13.9 - 30.6% D.W.) while protein and lipid were relatively low, 3.0 - 8.3% and 3.5 - 8.4%, of the dry weight, respectively. There were significant monthly variations in the three nutrients ($P < 0.0001$) but there was no significant sex difference. Multiple comparison test by the GT2 - method has shown that December and July protein concentrations were relatively high compared to the rest of the monthly samples (Appendix I - C). Even though high lipid values were recorded for the months December, August and September, multiple comparison test by GT2 - method did not show significant differences among months (Appendix I - D). Carbohydrate level in the food of O. niloticus in December was significantly higher than the levels recorded for October, November, May and September (Appendix I - E). Although multiple comparison

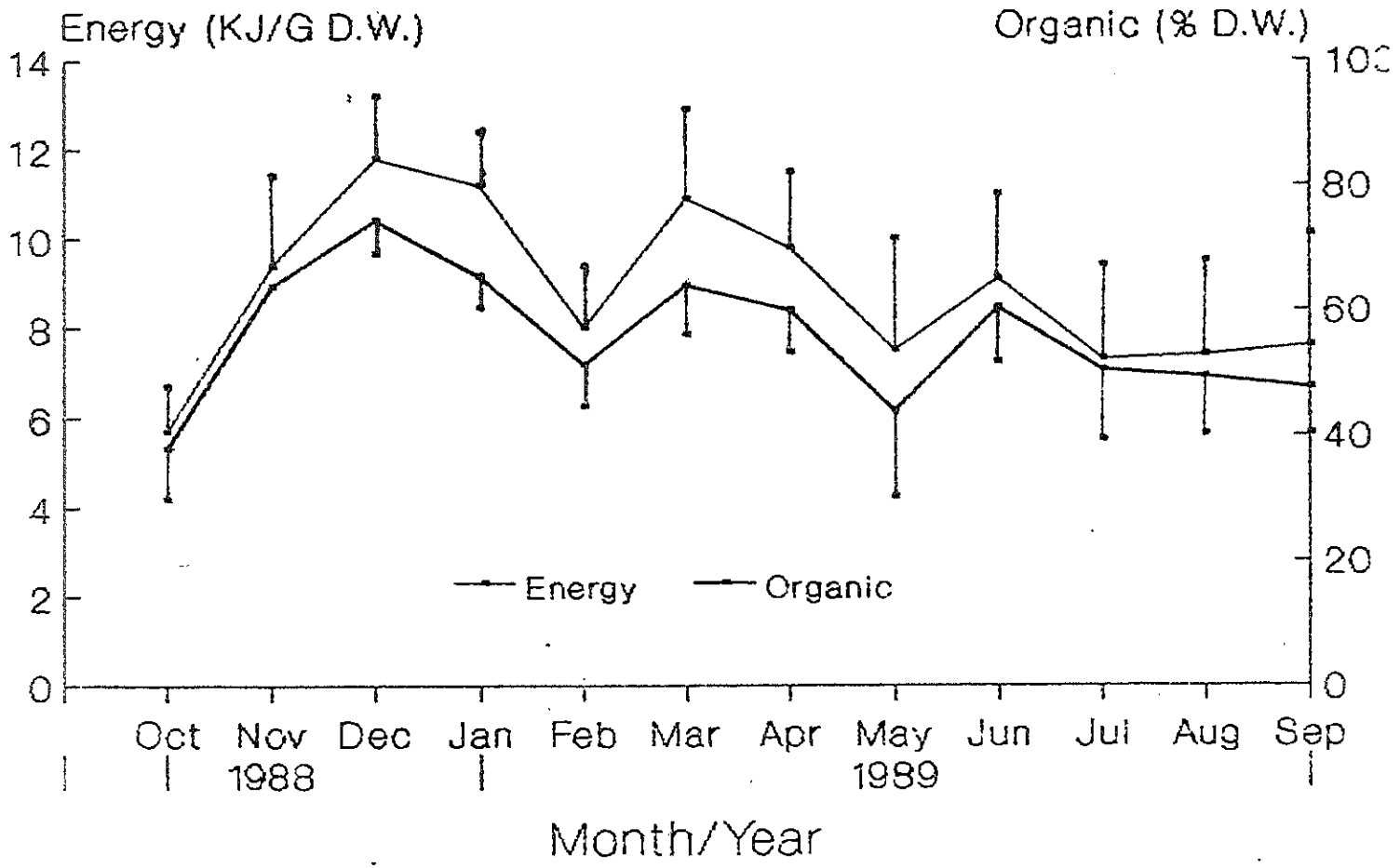


Fig. 3. The amount of organic matter and energy of the stomach contents of O. niloticus in Lke Ziway. Vertical bars are standard deviations.(Row data in appendix III- A and B).

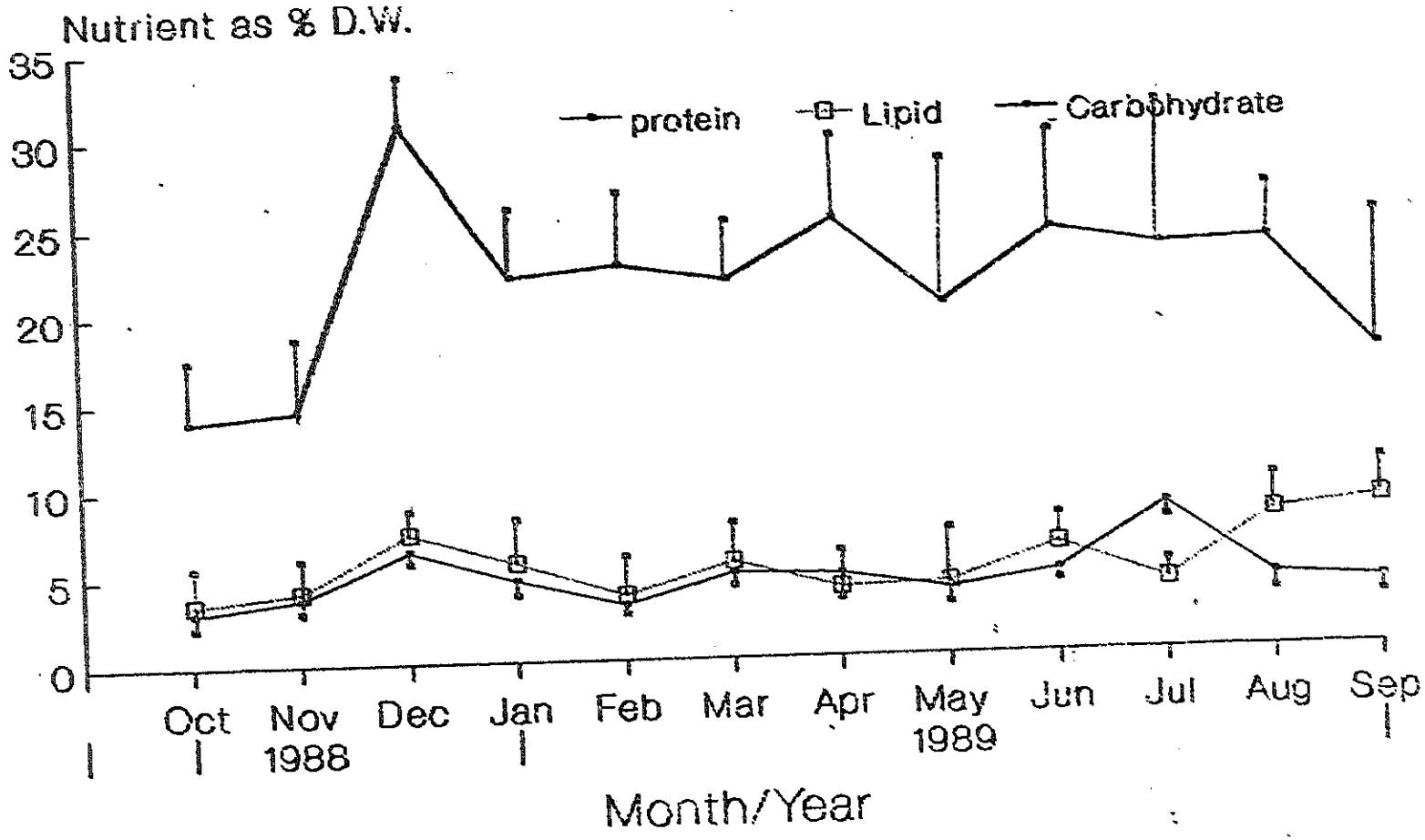


Fig. 4. Nutrient composition (Y-axis) of the stomach contents of O. niloticus in Lake Ziway. Vertical bars are standard deviations.(Row data in appendix III- C, D and E)

tests by GT2 - method did not show significant differences in most cases, the October sample was invariably lower in most nutrients.

The percentage of the AFDW that could be accounted for by the three nutrients, protein, lipid and carbohydrate, in the diet was about 57.0% (Fig. 5). Among the three nutrients, carbohydrate contributed the highest proportion, a mean of 39.1% AFDW. Protein contributed the least (mean = 8.4% AFDW) while lipid was intermediate (mean = 9.7% AFDW). Lipid and protein fluctuated relatively little compared to carbohydrate. The ranges for lipid and protein were 6.4 to 17.8% AFDW and 5.9 to 16.7% AFDW, respectively, while for carbohydrate the range was 22.7 to 46.7% AFDW.

The highest % AFDW for protein was recorded in July, while for lipid this was observed in September. 43.0% of the AFDW could not be accounted as nutrients in the form of protein, lipid or carbohydrate.

IV - 2 Assimilation efficiency

Assimilation efficiency (%) of different nutrients calculated using ash as a marker is summarized in fig. 6. At least 36.7% (range = 3.8 - 72.1%) of the total organic matter was assimilated. Protein was assimilated better than lipid and carbohydrate. Monthly assimilation efficiency for protein was in the range of 37.1 to 93.7% (mean = 73.3%). Protein assimilation was found to have appreciable positive correlation ($r = 0.595$, $n = 12$), although not strong, with protein level in the food. At least 15.6 to 74.4% (mean = 39.1%) of the carbohydrate in the food was assimilated by *O. niloticus* in Lake Ziway. Lipid was found to be assimilated least. Near zero values were repeatedly recorded and negative values were computed for two months, October and April. The mean assimilation efficiency for lipid was 13.3% (range = -47.3 to 43.5%).

Mean assimilation efficiency values for energy and AFDW were found to be 37.3 and 36.7 %, respectively. Moreover the monthly values show a similar pattern.

Assimilation efficiency of nutrients for three months was also computed using three indigenous markers, ash, HRA and HROM (Fig. 7). The use of HROM as a marker gave higher values in May and lower values in November and August. Values computed using ash and HRA as markers were high in November and August

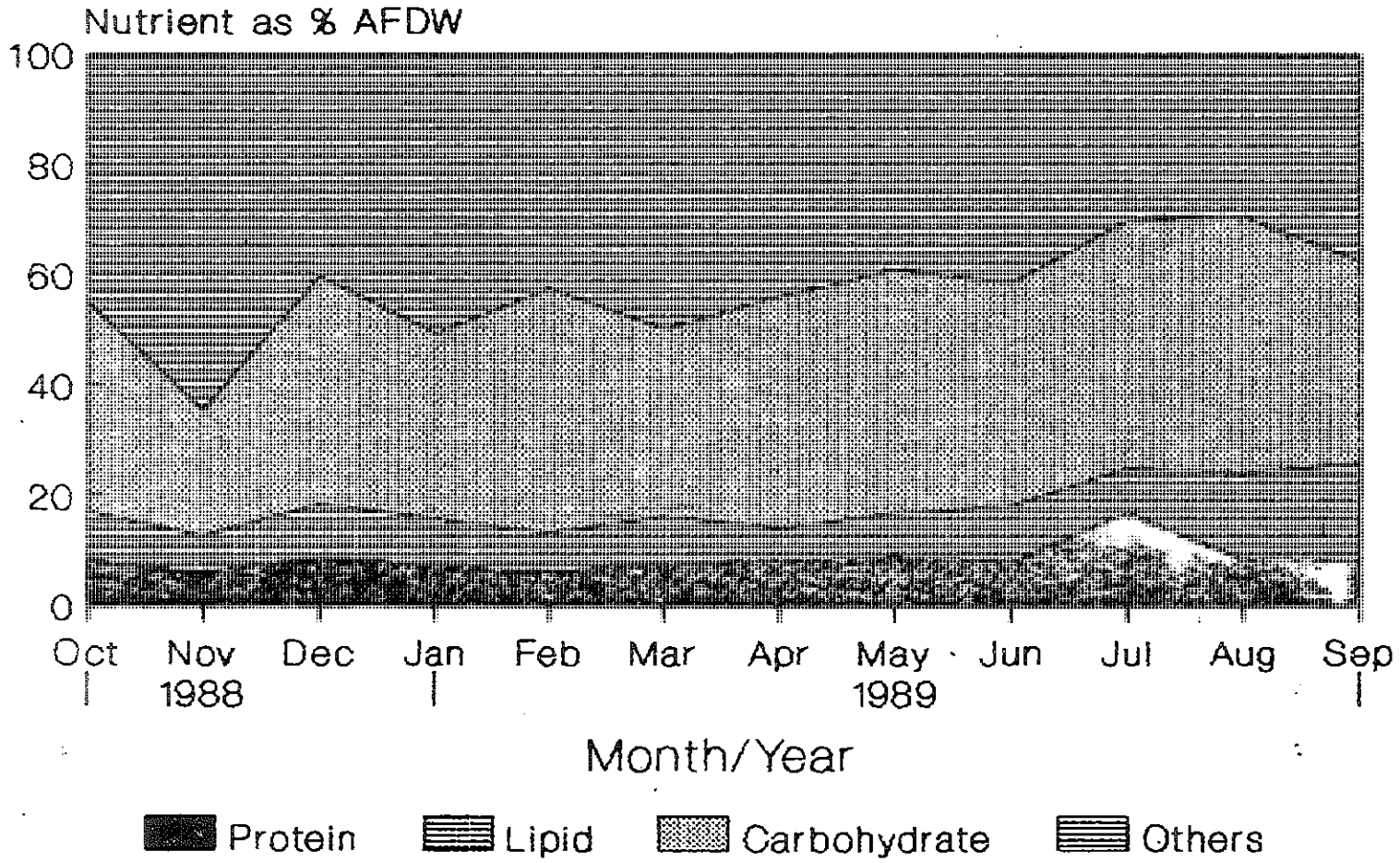


Fig. 5. Nutrient composition in the stomach contents of O. niloticus expressed as percentage of ash free dry weight(AFDW).(Row data is in appendix III-F).

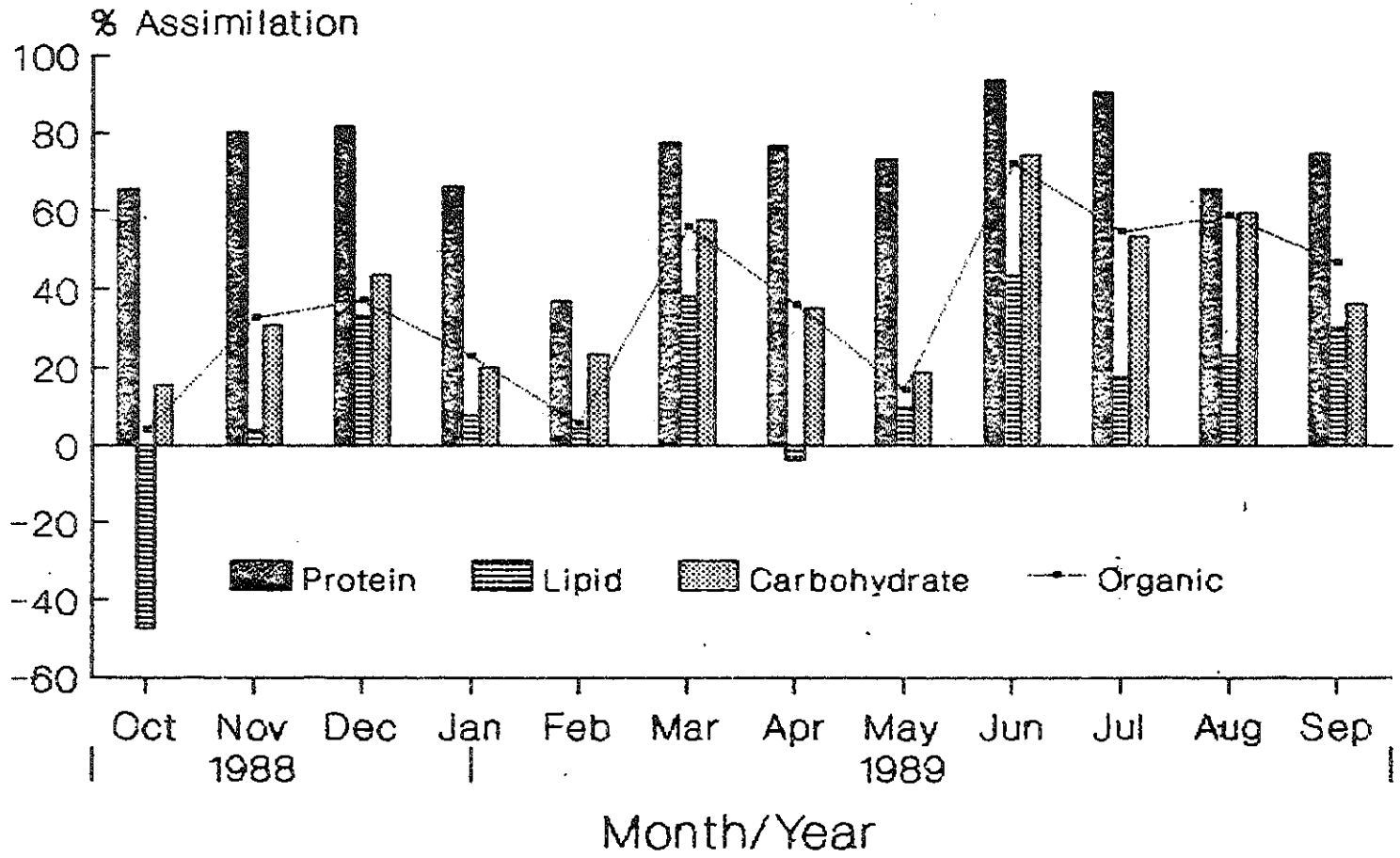


Fig. 6. Percentage assimilation efficiency of different nutrients in O. niloticus from Lake Ziway. (Row data is in appendix III-G)

Fig. 7-A

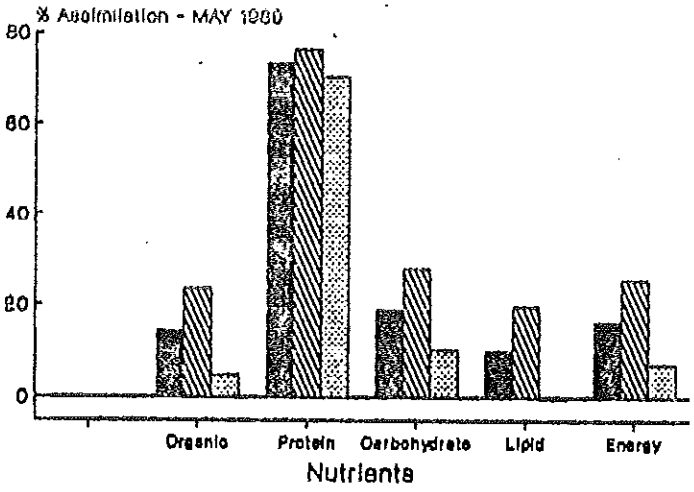


Fig. 7-B

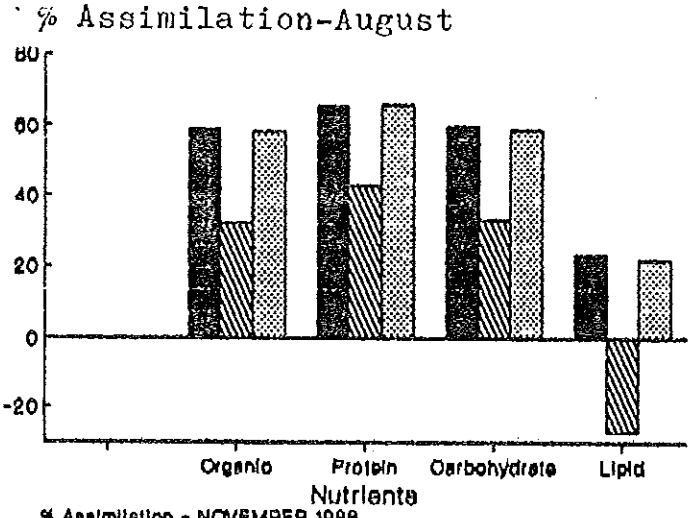
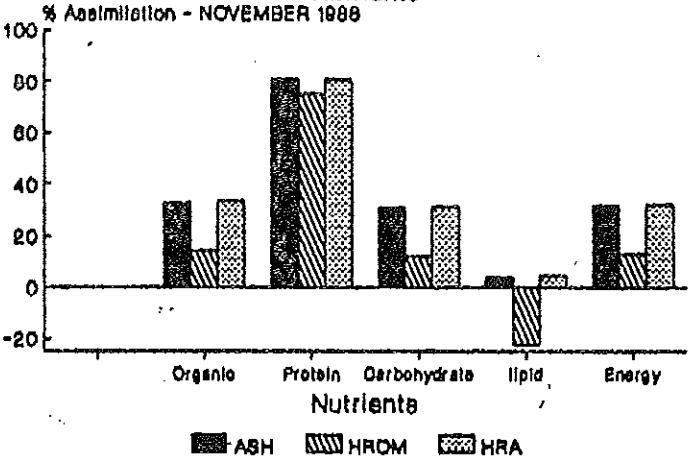


Fig. 7-C



Figs.7A, 7B and 7C. Percentage assimilation efficiency of different nutrients (including energy for May and November) determined using three indigenous markers: Ash, HROM and HRA for the three months May(Fig. 7A) August(Fig. 7B) and November(Fig. 7C).(Row data in appendix III-H).

and the corresponding values obtained using the two markers were essentially similar (Fig. 7).

IV - 3 Length - weight relationship

The length weight relationship was computed for each sex. The length-weight relationships of the male and female O. niloticus can be represented by the following equations.

1) Male $\log W = -1.553 + 2.874 \log L$ $n = 562$

$W = 0.028\ L^{2.874}$

$r^2 = 0.906$, $P < 0.0001$

2) Female $\log W = -0.974 + 2.448 \log L$ $n = 394$

$W = 0.106\ L^{2.448}$

$r2 = 0.852$, $P < 0.0001$

where W = weight in gram, L = length in cm.

IV - 4 Food quality and condition factor of fish

Both Fulton's condition and relative condition factor were computed for each fish and monthly mean values were determined. There was significant monthly variation in the condition of the fish ($P < 0.0001$) but, the difference in the condition of the fish between sexes was not significant ($P = 0.293$). Multiple comparison by GT2 - method showed that the condition of the fish in April was significantly lower from all other months (Appendix II - A).

Food quality determined from the ratio of mg digestible protein KJ digestible energy showed significant monthly variation ($P < 0.0001$)(Fig. 8). However, the quality of food consumed by the two sexes was not significantly different ($P = 0.885$). Multiple comparison test using GT2 - method showed that the protein - energy ratio of the food consumed in October was significantly higher (Appendix II - B). Food quality and condition of fish were found to have no significant correlation ($r = 0.012$).

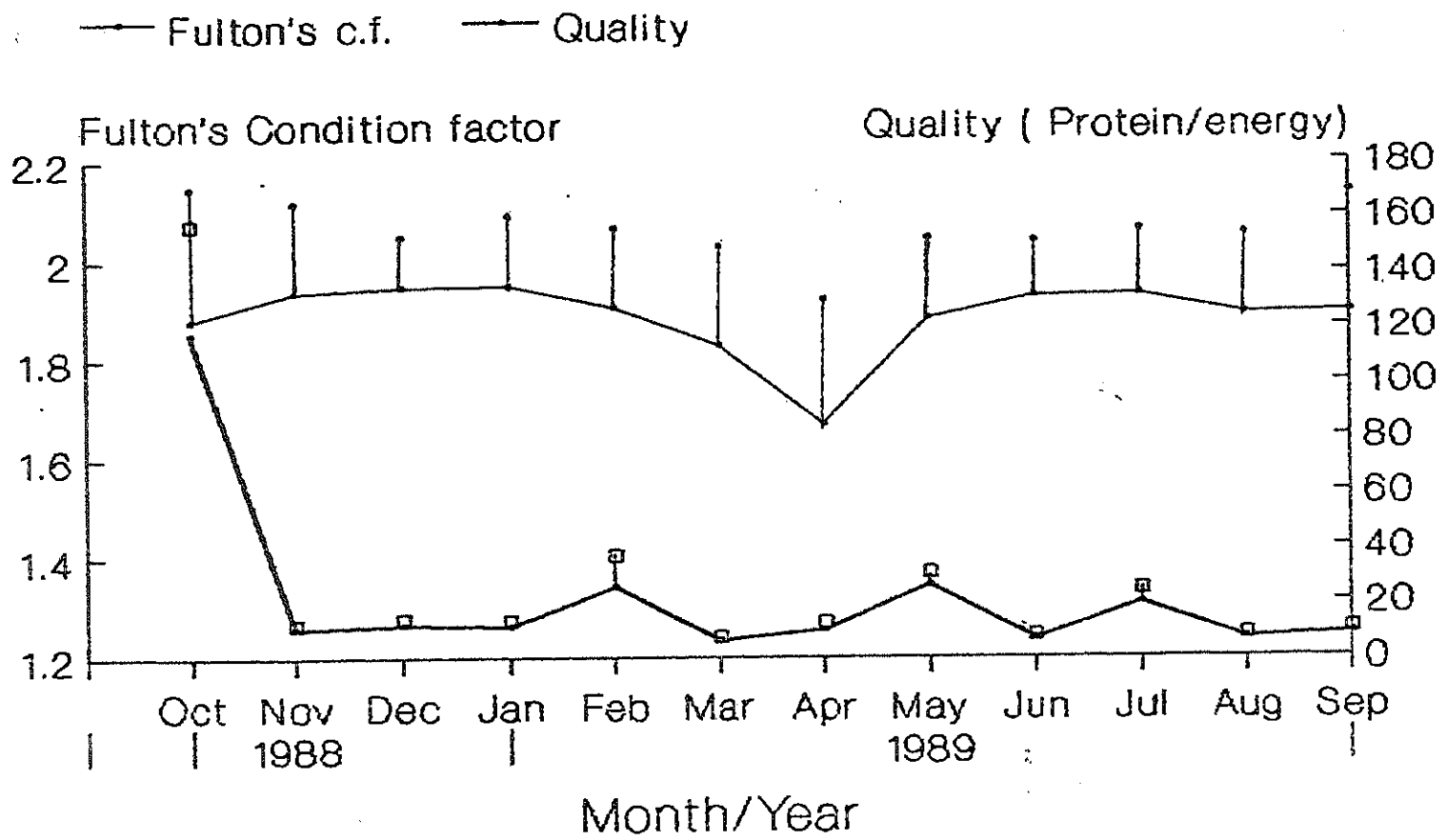


Fig. 8. Food quality (Y2-axis) and Fulton's condition factor (Y1-axis) of O. niloticus in Lake Ziway.(Row data in appendix III-I, J and K)

IV - 5 Water nutrients

Total inorganic nitrogen (NO_2 + NO_3-N and NH_3 + NH_4^+-N) was found to be high in August, middle of the rainy season (Fig. 9). Ammonia + ammonium-nitrogen was the dominant form of inorganic nitrogen while the other forms contributed very little to the total inorganic nitrogen. Nitrite + nitrate-nitrogen was consistently low throughout the sampling period. However a relatively higher concentration was recorded in September. Total inorganic nitrogen fluctuated very widely. It ranged from 9 ug/l in October to 153 ug/l in August.

Attempt was made to establish relationship between amount of total inorganic nitrogen and the amount of protein % AFDW in the food. However there was no significant correlation between the two ($r = 0.17$, $n = 12$).

Soluble reactive phosphorus (Ortho-phosphate) was more abundant than inorganic nitrogen. The highest soluble reactive phosphorus was recorded in May (280 ug/l $PO_4^{=}$-P). The lowest was recorded in August (56 ug/l).

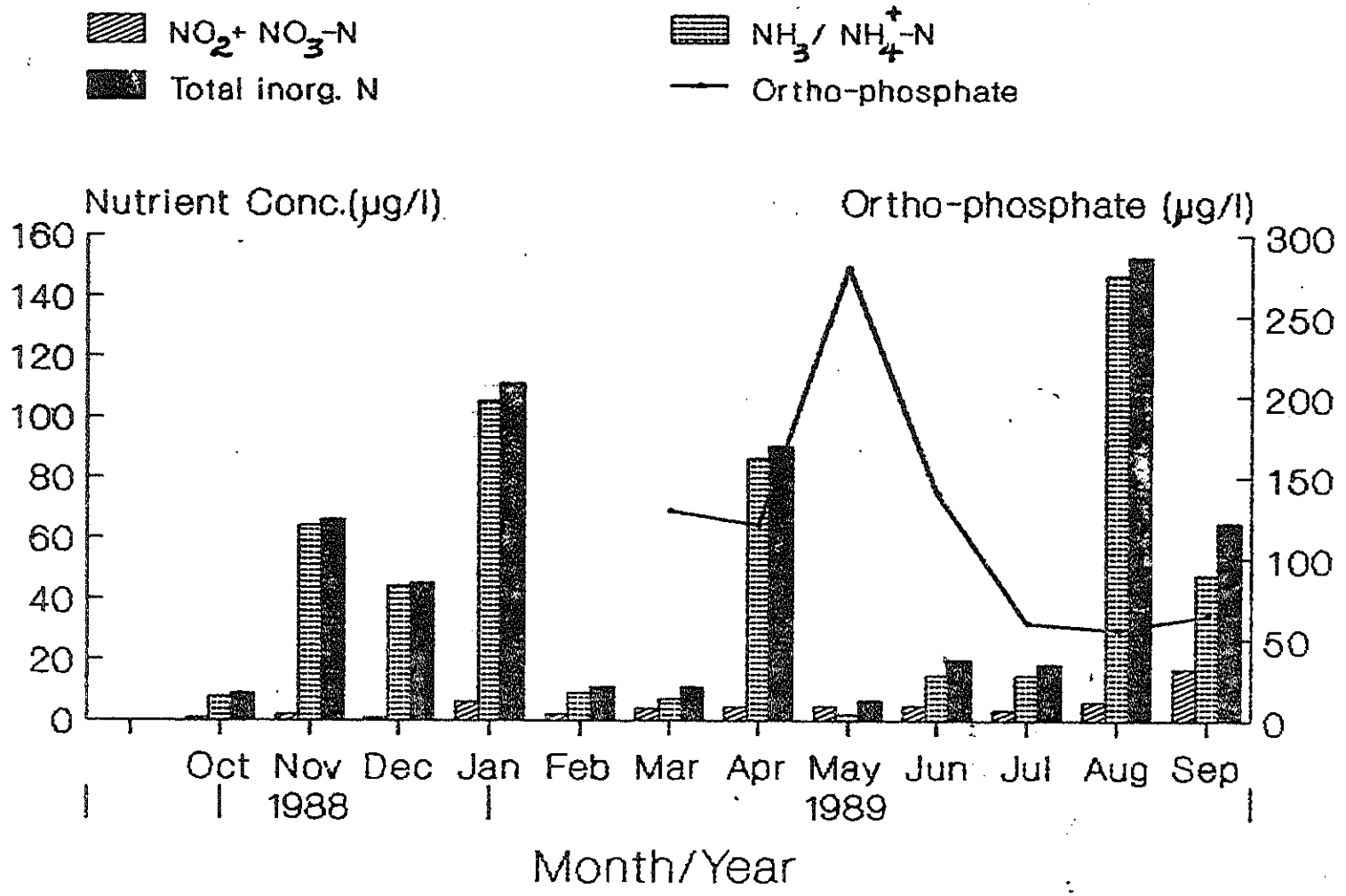


Fig. 9. Concentrations (µg/l) of different forms of inorganic nitrogen (Y1-axis) and ortho-phosphate (Y2-axis) of Lake Ziway during the study period. (Row data in appendix III-L).

V - DISCUSSION

Total organic matter in the food of O. niloticus in Lake Ziway was low, and ranged between 37.9 to 74.9% dry weight (mean = 55.7%) (Fig. 3). This is in close agreement with what was reported for the same species in the same lake by Zenebe (1988) and for O. mossambicus from the shallow man-made lakes of Sri Lanka by De Silva et al.(1984). Zenebe (1988) and De Silva et al. (1984) reported ranges of 47 - 71% and 34.4 - 64.4% dry weight, respectively. However the organic content of the food of O. niloticus in Lake Ziway is lower than that reported for the same species in Lake Awassa, a relatively deeper rift-valley lake (mean depth, Z = 11 m) (Getachew, 1987). Getachew (1987) reported the organic content of the food of O. niloticus in Lake Awassa to be high (mean = 82.0% D.W.). The low organic matter in the food of O. niloticus in Lake Ziway could be attributed mainly to the effects of the lake's hydrographic (water column structure) factors. Previous studies by Girma (1988) and Tsegaye (1988) have shown that Lake Ziway mixes frequently almost on a daily basis due to strong wind (Table 1-B) and nocturnal cooling. Mixing would bring about the resuspension of silt which in effect reduces the relative proportion of phytoplankton in the food and filtering this suspended silt with the phytoplankton in turn reduces the organic matter in the food.

Generally low organic matter was recorded during the long rainy season, the lowest being in October (Appendix I-A). The short rainy period (February - April) had also a substantial effect on the organic matter level in the food as is observed in May (Fig. 3). Rainfall in the form of run-off would wash and bring nutrients and inorganic material from the surrounding silt laden area (Ketema, 1986) into the lake. This raises the nutrient level and the proportion of suspended silt in the lake. Although higher nutrient level in the lake water would be expected to result in higher algal biomass (food of fish), the proportion of organic matter, however, may be diluted by the suspended silt and mud filtered with the food. This may result in very low organic matter in the food. A similarly low organic matter in the food, caused mainly by the effects of rainfall, was also reported by Getachew (1987) for O. niloticus in Lake Awassa.

During the dry season (October - January) (Table 1-B) the suspended inorganic material settles down and input of sediment is also low. The algal biomass becomes dominant compared to the sediments and hence the proportion of the organic matter in the food tends to be high (eg. December) (Appendix I-A). Zenebe (1988) also recorded the highest value (71% D.W.) for AFDW during this month.

Rainfall in the form of run off indirectly affects food quality by causing some seasonality on the phytoplankton community in the lake. Seasonality in most tropical lakes is governed by rainfall and wind regimes that affect nutrient level in the lakes (Lowe-McConnell, 1987). Adult O. niloticus in Lake Ziway mainly feeds on phytoplankton. It feeds on a wide range of algal species (Zenebe, 1988). All groups of algae are known to show some degree of seasonality in the lake water as well as in the stomach contents of O. niloticus analyzed (Tsegaye, 1988; Zenebe, 1988). Such periodicity of phytoplankton has an impact on the diet of an herbivorous fish species that mainly feeds on algae. Diatoms were reported to be dominant, surpassing blue-greens, in the phytoplankton community of Lake Ziway in October (Tsegaye, 1988). The presence of diatoms with silicified cell wall which is inorganic in nature, in higher proportion in the diet, when coupled with aforementioned factors may reduce the organic matter in the food at this time of the year (Fig. 3).

Assuming that protein, lipid and carbohydrate have average energy values of 23.0 KJ/g, 38.9 KJ/g and 17.2 KJ/g, respectively (Morwitz, 1968 cited in Boyd and Goodyear, 1971), the sum of protein, lipid and carbohydrate in the food of O. niloticus in Lake Ziway accounts for 6.82 KJ/g of the energy. Since this value is lower than the mean energy value measured in this study, 8.74 KJ/g, the rest of the energy, 1.92 KJ/g, is accounted for by organic matter other than protein, lipid and carbohydrate. Similarly low (9.69 KJ/g) energy value for a natural diet had also been recorded during a short term study by Hofer and Schiemer (1983) for O. mossambicus in Parakrama Samudra, one of the reservoirs of Sri Lanka. However, the energy value of the food of O. niloticus in Lake Ziway is low as compared to what was reported by Getachew (1987) and De Silva (1985), for the same species in Lake Awassa and for O. mossambicus in man-made lakes of Sri Lanka, respectively. O. niloticus in

Lake Awassa fed on diet that had an average energy value of 16.8 KJ/g while O. mossambicus in man-made lakes of Sri Lanka ingested food that had mean energy value of 11.6 KJ/g. The low energy value observed in this study could be explained by the low amount of lipid (mean = 5.32% D.W.) and organic matter (mean = 55.7% D.W.) in the food (Fig. 3).

Monthly variation in all nutrients appears to have a similar pattern (Figs. 3 and 4). Protein and lipid, however, showed some deviation from this trend during some months. Protein was highest in July and lipid was high both in August and September (Fig. 4). Taking light as a limiting factor for photosynthesis, Olesen and Ganf (1986) have shown its effect on photosynthetic partitioning in Microcystis aeruginosa. A greater proportion of the carbon fixed at low rates of photosynthesis was directed toward protein synthesis than to carbohydrate; at a higher rate of photosynthesis the converse was reported to occur. Euphotic zone and mixing depth of Lake Ziway are known to oscillate depending on episodes of mixing and wind conditions. The mixed depth was reported to be extended to 3.5 m while at the same time the euphotic depth of the lake was reduced to less than 50 cm in June and July (Girma, 1988). Primary production may be expected to be light-limited when the optical depth, the ratio of the freely mixed depth (Z_{mix}) to the euphotic depth (Z_{eu}), of the lake exceeds 4 to 5 (Wood et al., 1978). Optical depth calculations by Girma (1988) show that in June and July the values obtained were greater than 5. Optical depth in June was 7.2 while in July it was estimated to be 8.8. Therefore the phytoplankton community in Lake Ziway could be light-limited during this time of the year and is the possible cause for the high protein level observed in the diet of O.niloticus. Lipid was determined by extracting the food with diethyl ether in soxhlet apparatus. Diethyl ether in addition to lipid, extracts also other cellular components like pigments of various kinds eg. chlorophylls, carotenoids, and various sterols that are soluble in ether (Jordan and Hall, 1900 cited in Schneider and Flatt, 1975). The long rainy season for Ziway starts in June and extends till October (Table 1-B). The run off from the catchment and the inflow from the two rivers, Meki and Katar, that drain the surrounding plateau (see study area) result in an increase in the water level of the lake in August and September (Pers. obs.). This would bring inorganic nutrients into the lake

(Fig. 9) which would boost phytoplankton productivity and thus result in high algal biomass (Tsegaye, 1988). Chlorophyll "a" content was also reported to be high in June and July of 1988 (Tsegaye, 1988). It is likely that the high values for "ether- extractable" component obtained during the two months, August and September, could be not due to an increase in lipid level of algal cells but mainly due to the increment in the "ether - extractable" component of the food other than lipid.

A very high proportion (mean = 42.9%) of the organic matter in the food of O. niloticus in Lake Ziway could not be accounted for by the three nutrients, protein, lipid and carbohydrate (Fig. 5). Such a high value of unaccountable organic component has been reported for natural populations of fishes. Getachew (1987) reported 23.3% for O. niloticus in Lake Awassa, while De Silva et al. (1984), and Hofer and Schiemer (1983) found this portion of the organic matter in the diet of O. mossambicus in Sri Lanka to be 45.6% and 19.0% AFDW, respectively. Getachew (1987) suggested that this unaccountable portion of the AFDW was related to the detrital component in the diet. His suggestion can possibly be applied here as well to explain the high unaccountable portion of the AFDW. Even though the contribution of detritus to the diet of O. niloticus in Lake Ziway has not been quantified, its importance as a source of organic matter can not be overlooked (Zenebe, 1988). The water level of Lake Ziway fluctuates highly during the dry and rainy seasons of the year (Pers. obs.). During the dry season a significant portion of the littoral macrophyte will be located out-side the lake. As a result, a considerable portion of the area is covered by dead macrophytes in the dry season. However in the rainy season, when the water level rises this area will be inundated. It thus may serve as a source of autochthonous plant material. Allochthonous plant material can also be washed and brought into the lake by runoff or the two rivers, Meki and Katar. In addition, detritus that results from dead phytoplankton can be resuspended from the sediment during mixing. An appreciable portion of the nitrogen content of aged detritus derived from vascular plant tissue may exist in the form of non-protein nitrogen compounds; 1) amino sugars 2) complexes such as phenol - protein, Protein - lignin or protein - chitin 3) complexes of inorganic clays and amino groups and 4) nitrogen containing humic acids (Odum et al., 1979;

Wetzel, 1983). Pigments, hormones, nucleic acids and vitamins can also contribute to the unaccountable portion of the AFDW in the diet of O. niloticus in Lake Ziway.

When compared with the unaccountable component of the AFDW in the diet of O. niloticus in Lake Awassa (mean = 23.3%), the present finding from Lake Ziway is higher (mean = 42.9%). This could partly be explained by the different hydrologic and morphometric characteristics of the two lakes. Lake Awassa is a small but relatively deeper lake (Z = 11 m) than Lake Ziway with minimal annual water level fluctuation and is fed only by one river (Getachew, 1987). On the contrary, Lake Ziway is a big (see study area and Table 1-A) but shallow Lake with high annual water level fluctuation and is fed by two rivers. Therefore input of detritus from the catchment area, littoral macrophytes as well as resuspension from the sediment is expected to be higher in Lake Ziway than is in Lake Awassa.

Although the absolute protein level is low (Fig. 4), protein as % AFDW in the food is rather high (Fig. 5). Protein as % AFDW in Lake Ziway is higher than that reported for the same species in Lake Awassa (Getachew, 1987). The diet of O. niloticus in lake Ziway is dominated by blue-greens. Lyngbya and Microcystis are the major components of the diet of this fish and the latter is known to have high protein content (de Moor and Scott, 1985; Boyd, 1973; Kirilenko et al., 1975). It could thus be responsible for the high protein % AFDW observed. In Lake Awassa the diet of this fish species is dominated by the green algae Botryococcus brauni, and the contribution of the blue-greens is low (Getachew, 1989b).

Assimilation of the different nutrients in the diet was found to be variable (Fig. 6). Moriarty and Moriarty (1973b) and Getachew (1987) have reported similarly low assimilation efficiency values for total organic matter for the same species in Lake George and Lake Awassa, respectively. Particularly low assimilation efficiency values in the present study were recorded in October, February and May (Fig. 6). The low assimilation observed in October and May may be explained by the similar meteorological conditions that these months share. October and May are the last months of the long and short rainy periods, respectively (Table 1-B). The possible effects of the rainy season with respect to increasing the amount of detritus in the diet and

suspended inorganic material in the water have already been mentioned. Detritus derived from vascular plants contains refractory non - protein nitrogenous compounds that resist chemical degradation (Odum et al., 1979). In addition, Excessive amounts of inorganic material taken with the food reduces the efficiency of digestion in filter feeders and detritivores (Bowen, 1981). Moreover, the amount of pigments such as Chlorophylls, Carotenoids etc. increase during and after the rainy season. Since this component of the food does not lend itself to the action of low gastric pH or enzymatic action in the intestine of fish (Moriarty, 1973), it accounts partly for the low assimilation observed during these two months. An increase in the proportion of detritus, excessive inorganic material and the indigestible components in the food was therefore likely to have resulted in low assimilation in October and May. In February, the green algae contributed more than 35% to the total phytoplankton biomass (Tsegaye, 1988). Green algae also have cellulose cell wall which is less susceptible to lysis (Moriarty, 1973; Moriarty and Moriarty, 1973b). Hence it is plausible that assimilation efficiency of organic material is low in February.

Proteins were assimilated better than carbohydrates and lipids (Fig. 6). Mean assimilation for protein was 73.3 %. Fish generally can digest animal tissue protein at levels greater than 90 % (Beamish, 1972 cited in Buddington, 1979), but plant tissue proteins are less (40-80%) digestible (Kirilenko et al., 1975; Buddington, 1979; Montgomery and Gerking, 1980). Nevertheless, in fishes, proteins are assimilated better than carbohydrates and lipids (Kirilenko et al., 1975; Bowen, 1979; Hofer and Schiemer, 1983; de Moor and Scott, 1985; Getachew, 1987). Caution has to be taken while interpreting the results from this study, because protein was determined by Lowry's method (Lowry et al., 1951) which does not detect free amino acids in the food, except tyrosine and tryptophan (Folin and Denis, 1912 cited in Boyd, 1970). Proteins are broken down into their smallest units, amino acids, as food passes through the alimentary tract. But, it is likely that amino acids that are not absorbed after digestion will appear in the faeces and will not be detected by this method. This therefore may result in inflated assimilation efficiency values. Moreover in some of the aquaria studies done by some workers (Kirilenko et al., 1975) the fish were allowed to consume processed

feed. Such processing might have affected the digestibility values estimated (Buddington, 1980). Negative assimilation values for lipid that were found during the months October and April (Fig. 6) may have been due to the presence of high indigestible portion eg. pigments, indigestible lipids etc. in the "ether - extractable" component of the food. The exceptionally very high negative assimilation in October may have also resulted from the excessive amounts of inorganic material in the food observed during this month. Similarly near zero assimilation for lipid was recorded during some months (October and February) for O. niloticus in Lake Awassa because the food was dominated by indigestible lipid material of Botryococcus brauni (Getachew, 1987).

Assimilation efficiency values estimated using indigestible external markers such as Chromic acid are doubtful because of differences in the rates of movement of the food and external markers through the alimentary tract of fish (Bowen, 1978; De Silva and Owoyemi, 1983). Selective rejection of external markers was also reported (Hanley, 1987). In addition, incorporation of reference substances into fish diets requires grinding and alteration of the food (Buddington, 1980). The use of indigenous markers is therefore preferred to the use of external ones. The use of reference markers assumes that the reference marker is not digested or absorbed while passing through the digestive tract of fish. Any undetected absorption of the marker results in underestimation of assimilation efficiency. Dietary ash was reported to be absorbed by O. niloticus and HROM is not known to be assimilated by this fish species (Buddington, 1980). Since cellulase producing gut flora are absent in fish (Lobel, 1981), there is a wide consensus that fish are not able to assimilate HROM whose major components are cellulose and chitin (Stickney and Shumway, 1974; Buddington, 1980). A recent study, however, has demonstrated the presence of such gut flora that can digest cellulose in the digestive tract of two herbivorous fish species, Kyphosa corneli and Kyphosa syndeyanus (Rimmer and Wiebe, 1987). Whenever cellulase activity was reported in fish (Prejs and Blaszezyk, 1977) it was associated with the presence of highly processed detritus in the gut. Under such conditions the possibility of cellulose assimilation should not be overlooked. Higher assimilation values have been recorded when researchers (Buddington, 1980; Getachew, 1987; Zenebe,

1988) used HROM as a marker, similar to what was observed in May (Fig. 7-A). It is not clear, however, why assimilation efficiency estimates for the different nutrients that are calculated using HROM are relatively higher during May and low during November and August as compared to values obtained using ash and HRA. Although the differences between the means of their results were not significant, a similar result was reported by De Silva et al. (1984). The consistency in assimilation values obtained when ash and HRA were used, is a good indicator that one of the two may serve as a marker in Lake Ziway. But, further study is needed before any decision is made on the use of any of the reference markers.

The quality of the food expressed as the ratio of mg digestible protein to KJ digestible energy showed little variation throughout the study period, except one month i.e. October (Fig. 8 and Appendix I-A). The exceptionally high protein:energy ratio that was found in October is the result of the combined effects of protein and energy in the food of the fishes as well as their assimilation. Low assimilation of the already low energy when combined with a relatively high protein as % AFDW and high protein assimilation results in a very high Protein:energy ratio. In the rest of the months the quality of the food in Lake Ziway ranges from that supporting minimum to maximum growth (Fig. 8). For O. mossambicus a ratio of 4 was enough for maintenance while 25 was needed for maximum growth (Bowen, 1982). Anything higher than 25 does not support growth. Protein at higher levels is in excess of the animals ability to utilize it anabolically and thus growth decreases presumably as a result of energetic cost of protein catabolism (Boyd and Goodyear, 1971; Bowen, 1982).

The condition of O. niloticus in Lake Ziway did not show significant variation for most part of the year, except during April (Fig. 8 and Appendix II-A). The lowest condition recorded for the same species in the same lake by Zenebe (1988) was in March. In this study, it was also found out that there was no relationship between the mean monthly condition of fish and the respective protein:energy ratio of the dietary material (Fig. 8). In fish, condition is assessed as the measure of deviation of the mass of an individual from the average mass for the length of the population and it is well established that it gives an indication of the ecological and physiological state of the population. Condition of fish can be affected by long - term

factors such as the environment, food supply, food quality, degree of parasitization, reproductive activity and feeding rate (Le Cren, 1951; Bowen, 1979; Getachew, 1987). A study done on the reproductive biology of O. niloticus in Lake Ziway (Zenebe, 1988) shows that this fish population reproduces throughout the year with peak reproductive activity from January to March. The body of these fish prior or during this period spends its protein and energy for the physiological changes needed for reproduction, that is production of sperm and egg in the male and female, respectively. Because guarding males pay great attention to the cleanliness of the central depression of the nest, particularly where detritus tends to accumulate (Fryer and Iles, 1972), it would be expected that males of O. niloticus during this period spend most of their time on this activity rather than feeding.

O. niloticus is a maternal mouth - brooder species. In mouth - brooders the female fasts during the early stages, and probably often throughout the brooding period, which is between 20 and 30 days in the Genus Tilapia (Fryer and Iles, 1972). Starvation during fasting will have a significant effect on the condition of the female fish. Therefore the reason why fish had poor condition in April in Lake Ziway could be the high reproductive activity in the preceding months. Such a negative effect of reproductive activity on the condition of fish, when there is actually a qualitatively adequate food, was observed for O. niloticus population in lake Awassa (Getachew, 1987).

In Lake Awassa food quality was mainly related to rainfall effects that influence the level of nutrients in the lake. And, consistently low or consistently high quality food was recorded in more than three consecutive months. In the dry season the quality was high while in the rainy season it was low. Moreover it was reported that condition factor was not sensitive enough to detect minor changes in food quality that occur over a short period of time. In Lake Ziway the quality of the food did not show as such marked variation for most part of the year (Appendix II-B) and whatever variation was observed in quality it did not occur on more than two consecutive months. Therefore, condition factor might have not been sensitive enough here as well to detect the changes that occurred in the quality of food.

Comparison of conditions of populations of O. niloticus in the two lakes, Ziway and Awassa, shows that the Lake Ziway population is in a

relatively inferior condition. Computations of length - weight relationships in lake Ziway gave the equations; $W = 0.028\ L^{2.874}$ and $W = 0.106\ L^{2.448}$ for male and females, respectively. For the Lake Awassa population similar computations by Getachew (Pers. comm.) from samples collected using nets of similar mesh size gave the equations $W = 0.03\ L^{2.860}$ for the males and $W = 0.022\ L^{2.970}$ for the females, where W = weight in gram and L = total length in cm. To verify the implications of these equations the following example is given. A male O. niloticus that has a total length of 25 cm will have a total weight of 291g in Lake Ziway and 299g in Lake Awassa, while a female fish with the same total length will have a total weight of 280g in lake Ziway and 312g in Lake Awassa. From the results obtained by substituting 25 for L (Total length), it is evident that the Lake Awassa population of O. niloticus appears to be in a better condition (higher weight for a given length) than the Lake Ziway population. Weight calculations for a fish of 20 cm further reveals that the difference in condition between the two populations gets wider as fishes grow longer (older). The results of this study support what has been pointed out by De Silva (1985). He stated that " although within a population the condition may change with the reproductive status of the population etc., the overall condition of a population is determined by the nutritional value of the material ingested, and that the measure of condition of a population is indicative of the nutritional status of the latter.". The protein:energy ratio of the diet of O. niloticus in Lake Ziway appears to be better than that of the same species in Lake Awassa (Getachew, 1987). However, Bowen and Ahlgren (unpublished) stress that growth may be restrained when the digestible organic matter in the food is low, even when there is sufficient protein to support growth. Digestible organic matter in the food of O. niloticus in Lake Ziway as observed in this study is lower than that of the same species in lake Awassa, partly explaining the inferior condition observed in the Lake Ziway population. It is therefore conceivable that, the protein:energy ratio should be used to compare the quality of food of two populations whenever there is a similar amount of digestible organic matter in the diets of the two populations under consideration (Bowen and Ahlgren, unpublished).

A factor that has been studied for both populations and is potentially capable of influencing condition of fish, in addition to food quality, is

feeding rate. Growth of O. niloticus is also known to be markedly affected by its feeding rate (Teshima et al., 1986 cited in Teshima et al., 1987). Comparison of the feeding rates of the two populations show that the lake Awassa population has a higher feeding rate, 11.5% body weight per day, (Getachew, 1989a) than O. niloticus population in Lake ziway, 7.6% body weight per day (Zenebe, 1988). A very high feeding rate (31.2% body weight per day) was reported for juvenile O. mossambicus in Sri Lanka by Hofer and Schiemer (1983), but since the length-weight relationship was not indicated, comparison of condition was not possible to make. Since feeding intensity may be seasonal (Siddiqui, 1977) further study is needed in this respect. Zenebe (1988) suggested that the low feeding intensity of O. niloticus in lake Ziway was due to the high temperature fluctuation and wind induced mixing of the lake that forces the fish to spend most of its time and energy on maintaining its balance rather than feeding. In addition, the nature of the food eaten could also be another influencing factor. The diet of O. niloticus in Lake Awassa is dominated by Botryococcus brauni, a green algal species (Getachew, 1989b) while in lake Ziway Lyngbya and Microcystis are the most important components of the diet in terms of their contribution to the AFDW (Zenebe, 1988). It is well documented that blue-green algal blooms in the natural environment are associated with toxicity and massive animal kill (Amha and Wood, 1982; Caramichael, 1988). Toxicity associated with the presence of Microcystis has also been repeatedly reported (Hanazato and Yasuno, 1987; Caramichael, 1988). Though gastric evacuation rate is known to be mediated through nervous stimuli triggered by chemicals (Bromley, 1987), to my knowledge, the effects of the toxic chemicals of Microcystis and/or other blue-green algal species on feeding rate have not been documented. However, aquaria experiments using processed feed have shown that tilapia fed on blue-green algae did not show any deviation from the normal physiological condition including feeding (Kirilenko et al., 1975). In any case the combined effect of poor quality food and low feeding rate is likely to explain the inferior condition of fish in Lake Ziway as compared to that in Lake Awassa.

O. niloticus populations in poor condition are known to mature at a much smaller size than populations in good conditions (Lowe-McConnell, 1982). Although the average maturity size for O. niloticus in Lake Ziway was not

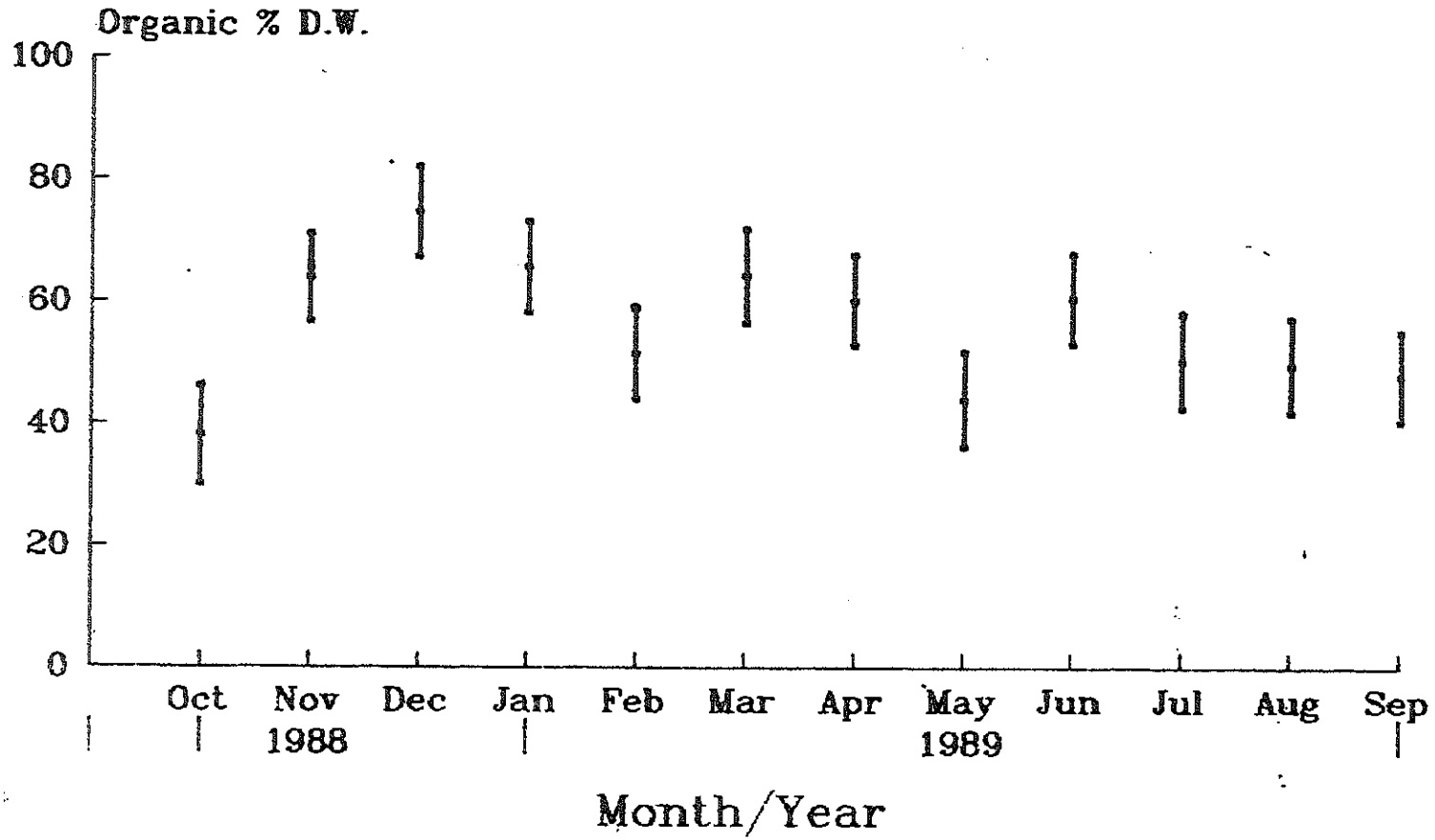
indicated, the smallest ripe male and female were reported to have total lengths of 16.2 and 13.8 cm, respectively (Zenebe, 1988). In Lake Awassa the average maturity size is estimated to be between 19 and 20 cm (Demeke Admasu, pers. comm.). Moreover, since bigger species are known to mature for the first time at larger sizes and growth rate is directly related to maximum size (Fryer and Iles, 1972), the knowledge of growth rate of O. niloticus in lake Ziway and its change with time may reveal important information that probably would help in explaining further effects of food quality on this population.

Total inorganic nitrogen (NO_2 + NO_3 + NH_3 + NH_4^+ - N) was more or less similar to that reported by Girma (1988), except for some months. Unlike Girma's (1988) finding the dominant form of inorganic nitrogen was found to be NH_3 + NH_4+ - N, which could be due to the effect of the sediment of this mixed shallow lake. In this study, a relatively higher nitrate concentration was recorded in September (Fig. 9), probably because of higher nitrate input from the catchment area and the littoral zone. The concentrations of NO_2^- + NO_3^- - N and NH_3 + NH_4^+ - N observed in this study for the month November was consistent with the findings of Schroder (1984).

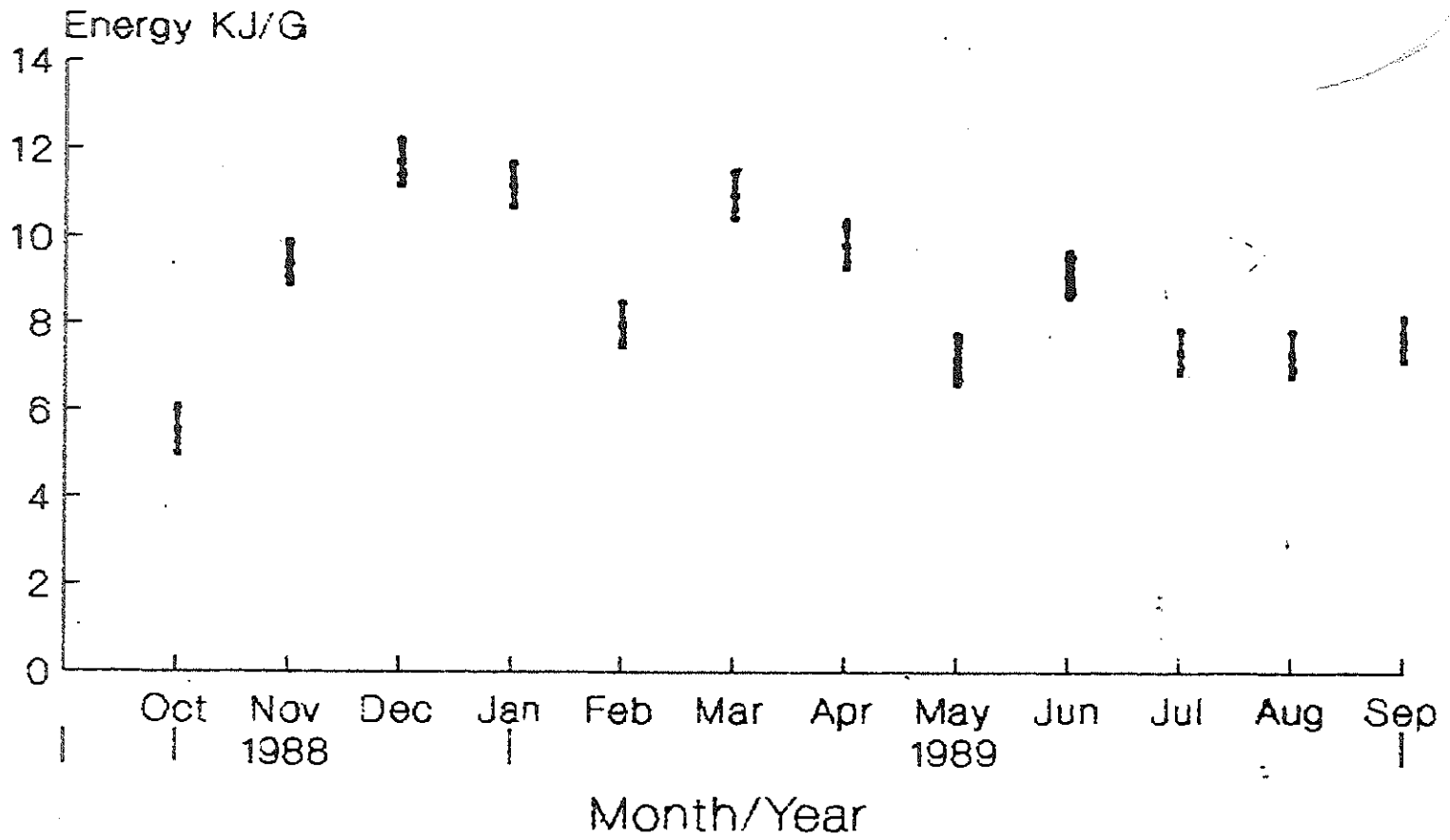
An experiment done on two green and four blue-green algal species (including Microcystis) by Piorreck et al. (1984) showed that both groups (green and blue-green algae) could be manipulated to produce higher protein, Chlorophyll and biomass by increasing the nitrogen concentration in the nutrient medium. In the same experiment the green algae produced relatively low lipid material when the nitrogen level increased in the nutrient medium. The blue-green algae, however, did not show any significant changes in lipid composition, when the nitrogen concentration in the nutrient medium was varied. Piorreck and Pohl (1984) observed a decline of protein content (%dry weight) of Microcystis aeruginosa (and other algal species) when the nitrogen level in the nutrient medium was depleted with time. Although the final concentration of nitrogen attained in the medium after depletion by algal consumption was not indicated, the protein level in the algal cells was reduced from 29.2% dry weight to 15.8% dry weight with in 35 days. Dry weight protein of 29.2% was initially attained using nutrient medium of 0.01 g/l nitrogen concentration. Differences in lipid metabolism between green and blue-green algae were also noted by Piorreck and Pohl (1984). The levels of

nitrogen used in these experiments were extremely high, in the range of 0.003 to 1.000 g/l. This therefore may not give clues to the expected changes of protein or lipid level in algal cells at lower level of nitrogen concentration and fluctuation. The level of TIN in Lake Ziway is very low (maximum = 0.000153 g/l) and is not comparable to that used by the above workers. As a whole, nutrients in the lake water (TIN and ortho-phosphate) seem not to play a direct influential role on the quality of the food (algae) of O. niloticus.

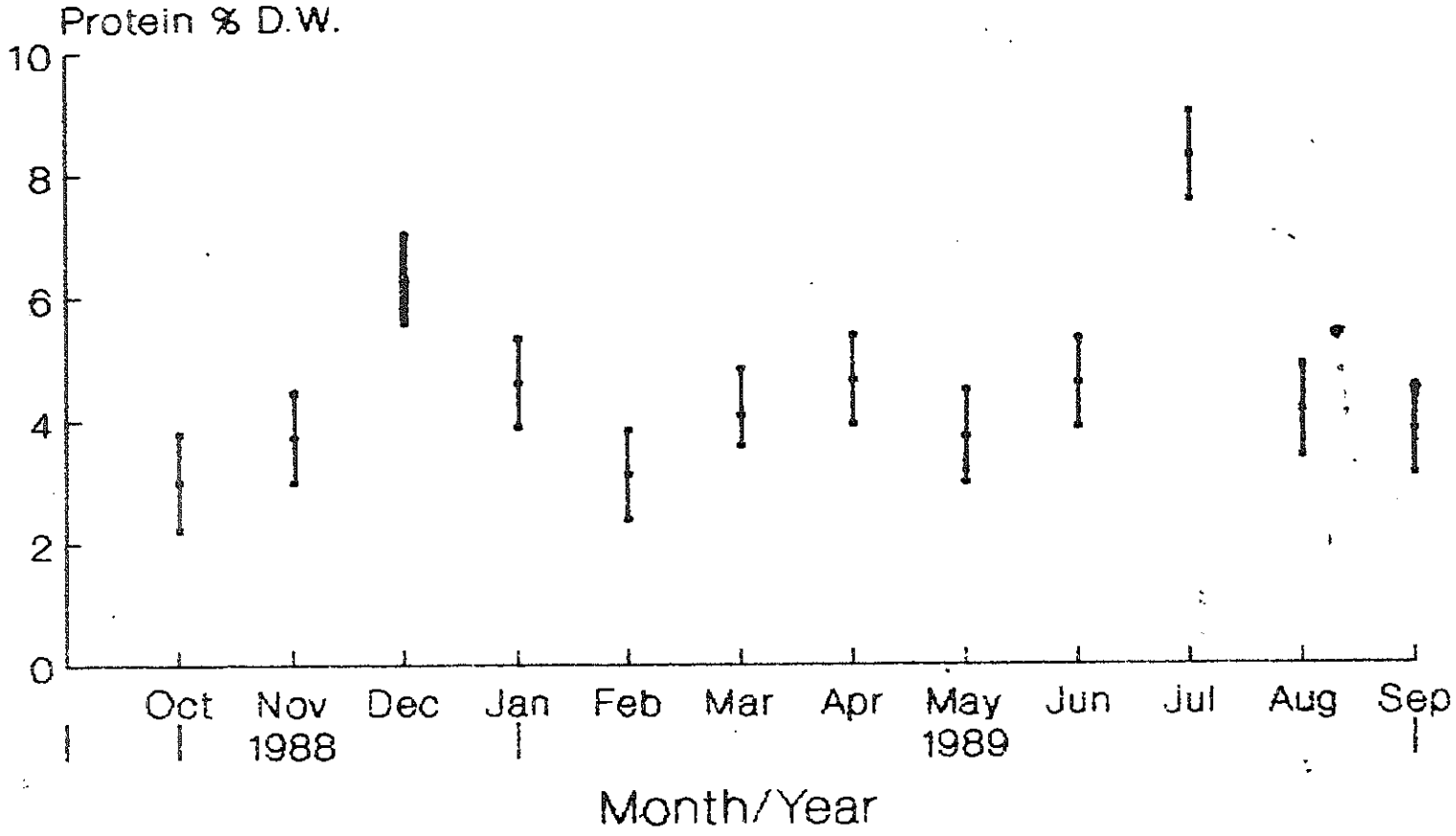
VI - APPENDIX



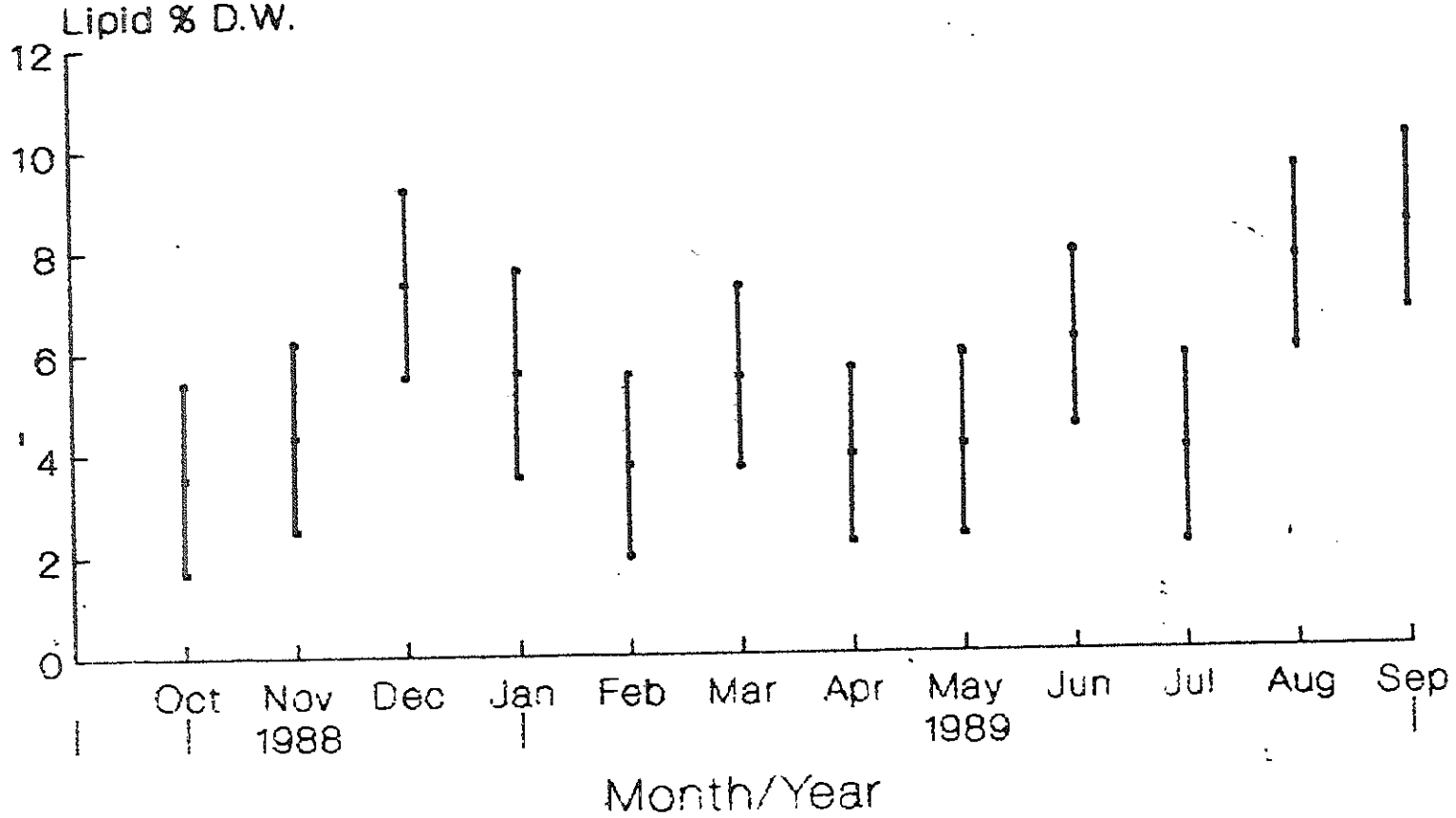
App. I-A. 95% comparison intervals by the GT-2 method for the means of organic(% dry weight) in the food of C. niloticus in Lake Ziway. Means whose intervals do not overlap are significantly different.



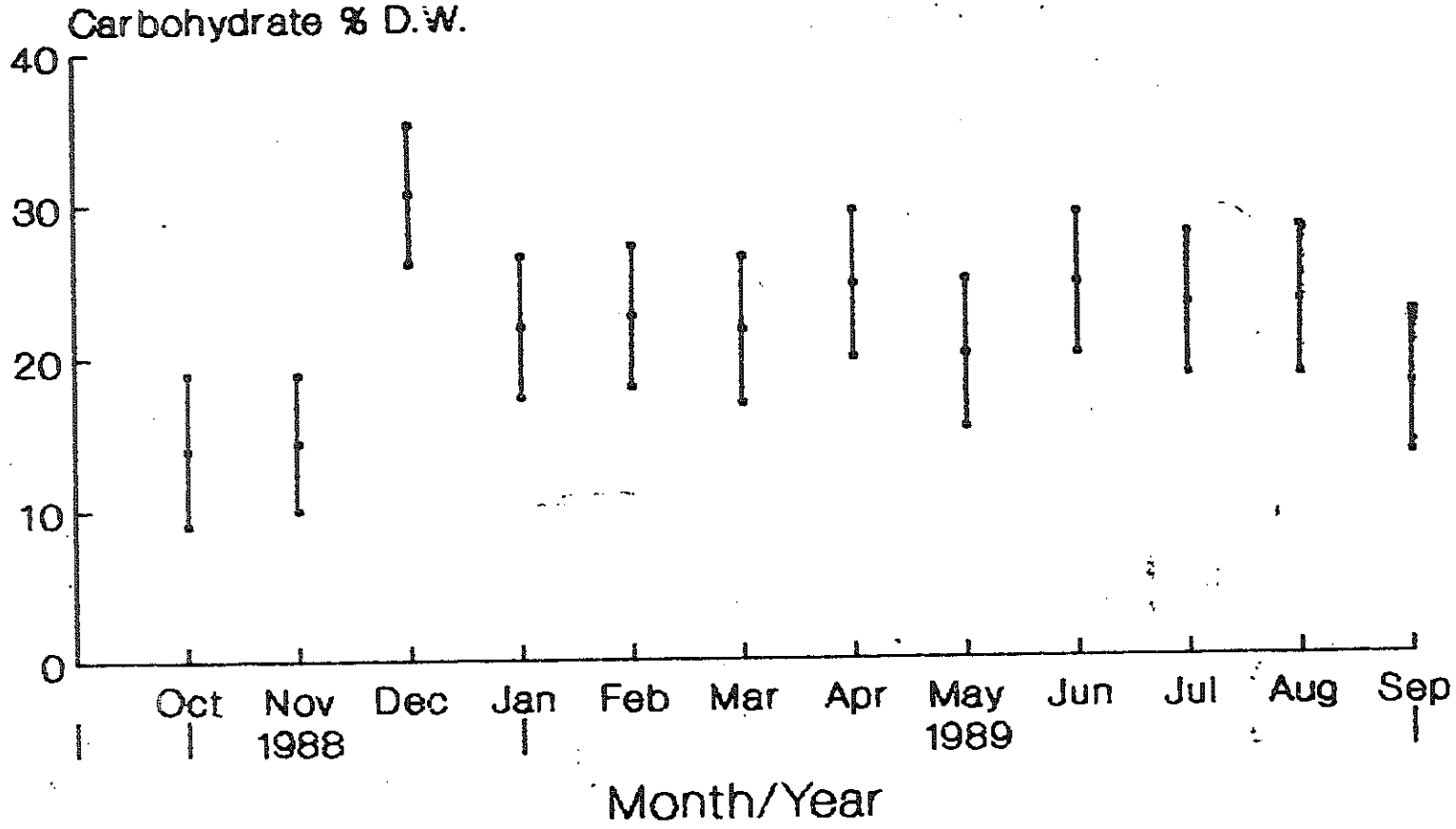
App. I-3. 95% comparison intervals by the ST-2 method for the means of energy in the food of O. niloticus in Lake Ziway. Means whose intervals do not overlap are significantly different.



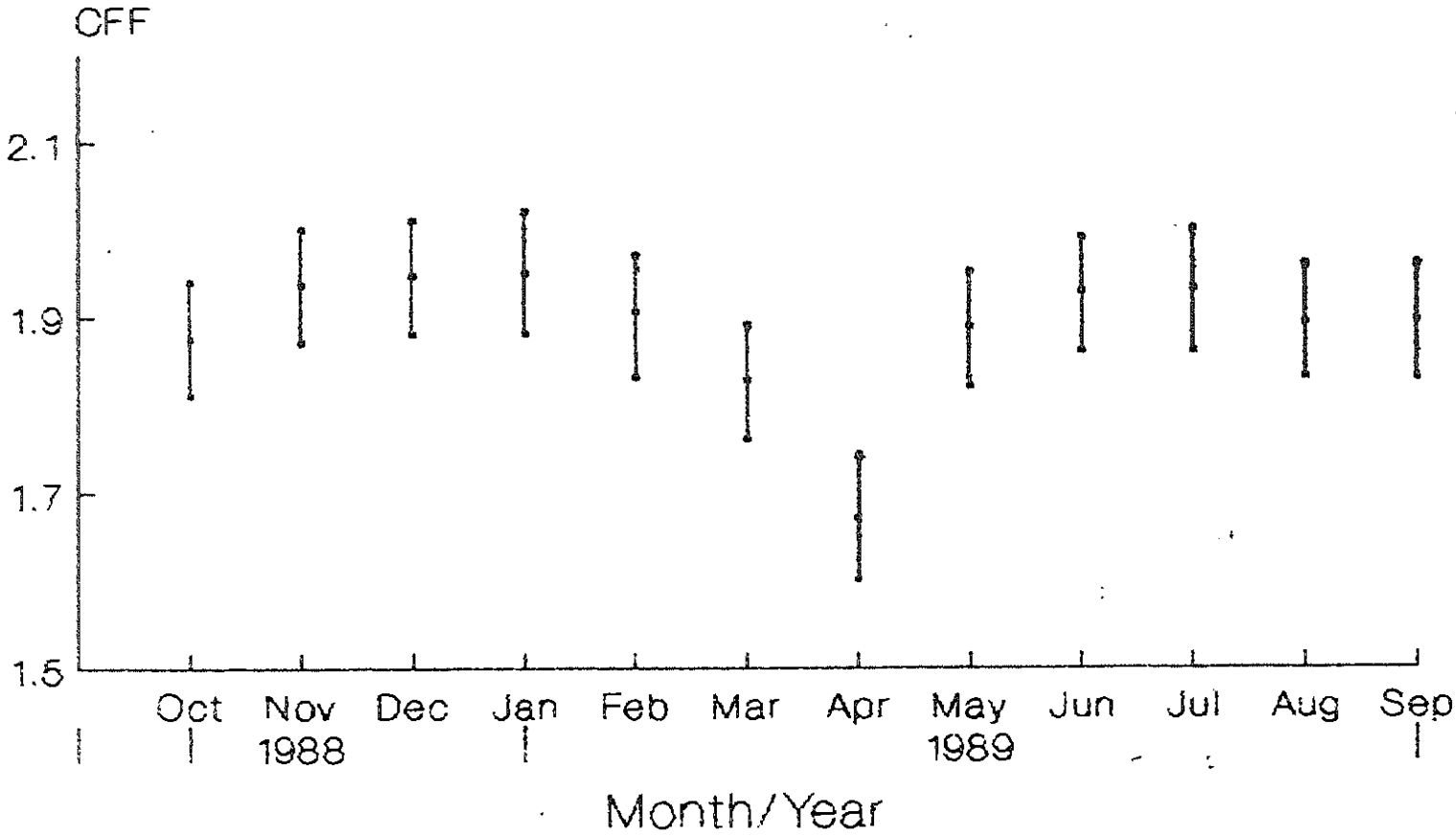
App. I-C. 95% confident intervals by the GT-2 method for the means of protein concentration in the food of C. niloticus in Lake Ziway. Means whose intervals do not overlap are significantly different.



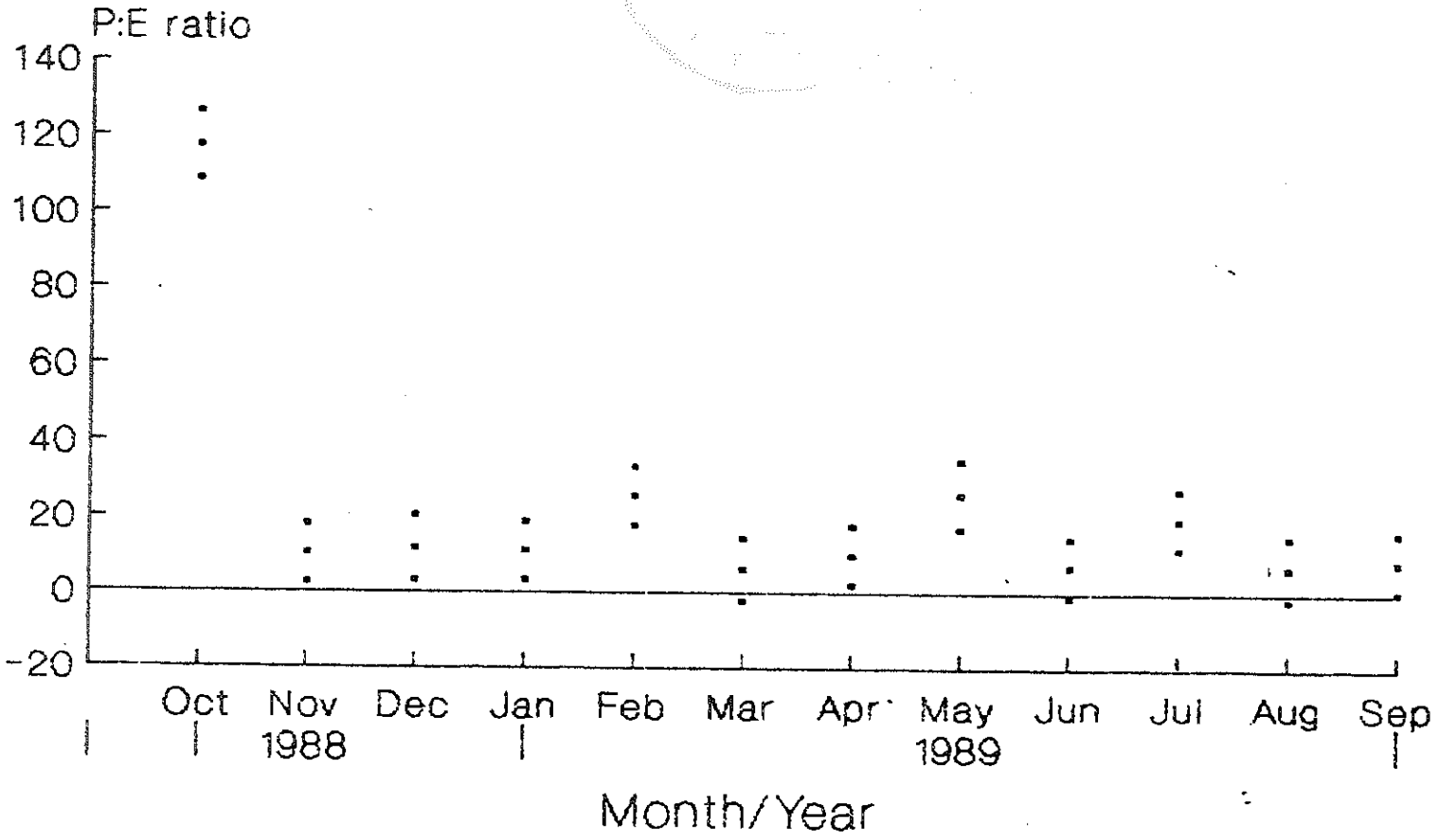
App. I-D. 95% comparison intervals by the ST-P method for the means of lipid concentration in the food of C. niloticus in Lake Nkuruba. Means whose intervals do not overlap are significantly different.



App. I-E 95% comparison intervals by the GT-2 method for the means of carbohydrate in the food of O. niloticus in Lake Ziway. Means whose intervals do not overlap are significantly different.



App. VI-A. 95% confidence interval by the T-method for the means of Fulton's condition factor of O. niloticus in Lake Kiwaw. Means whose intervals do not overlap are significantly different.



App. II-3 95% confident intervals by the GT-2 method for the means of protein:energy ratio of the food of *O. niloticus* in Lake Ziway. Means whose intervals do not overlap are significantly different.

App.III-A. Total organic matter % dry weight ± S.D. in the food and faeces and the respective monthly assimilation efficiency (%) calculated using ash as a marker.

	STOMACH CONTENTS (Food)	RECTAL CONTENTS (Faeces)	ASSIMILATION EFFICIENCY
October	37.9 ± 8.1	37.0 ± 8.0	3.8
November	63.8 ± 0.0	54.3 ± 9.2	32.6
December	74.4 ± 5.4	61.2 ± 7.0	37.2
January	65.4 ± 5.0	59.4 ± 6.4	22.8
February	51.3 ± 6.6	49.9 ± 6.8	5.4
March	64.0 ± 7.9	44.0 ± 10.1	55.8
April	60.0 ± 6.8	49.0 ± 7.1	36.0
May	43.9 ± 13.7	40.2 ± 13.1	14.1
June	60.3 ± 8.6	29.8 ± 6.6	72.1
July	50.4 ± 11.1	31.5 ± 6.8	54.7
August	49.4 ± 9.2	28.7 ± 5.4	58.8
September	47.6 ± 10.9	32.6 ± 7.2	46.8
Mean	55.7 + 10.6	43.1 + 11.5	36.7

App.III-B Energy (KJ/g dry weight ± S.D.) in the food and faeces and the respective monthly assimilation efficiency (%) calculated using ash as an indigenous marker.

	FOOD	FAECES	ASSIMILATION EFFICIENCY
October	5.7 ± 1.0	5.6 ± 1.1	3.2
November	9.4 ± 2.0	8.1 ± 1.4	31.7
December	11.8 ± 1.4	9.6 ± 1.2	37.9
January	11.2 ± 1.2	9.8 ± 1.2	25.0
February	8.0 ± 1.4	7.6 ± 1.6	6.3
March	10.9 ± 2.0	7.1 ± 2.5	58.0
April	9.8 ± 1.7	7.9 ± 1.6	36.8
May	7.5 ± 2.5	6.7 ± 1.7	16.2
June	9.1 ± 1.9	4.5**	72.1*
July	7.3 ± 2.1	4.8**	54.7*
August	7.4 ± 2.1	4.3**	58.8*
September	7.6 ± 2.5	5.2**	46.8*
Mean	8.74	6.76	37.3

* values taken from total organic matter.

** values obtained from back calculations using assimilation values(*) of total organic matter.

App.III-C. Protein as % dry weight ± S.D. in the food and faeces and the respective monthly assimilation efficiency (%) calculated using ash as a marker.

	FOOD	FAECES	ASSIMILATION EFFICIENCY
October	2.99 ± 0.80	1.04 ± 0.50	65.70
November	3.70 ± 0.74	0.92 ± 0.30	80.30
December	6.29 ± 0.70	1.50 ± 0.40	81.80
January	4.59 ± 0.84	1.81 ± 0.60	66.40
February	3.10 ± 0.54	2.01 ± 0.70	37.10
March	4.81 ± 0.76	1.69 ± 0.70	77.50
April	4.63 ± 1.44	1.38 ± 0.00	76.60
May	3.70 ± 0.90	1.05 ± 0.30	73.40
June	4.60 ± 0.60	0.50 ± 0.20	93.70
July	8.26 ± 0.84	1.09 ± 0.90	90.50
August	4.10 ± 1.00	2.00 ± 1.60	65.40
September	3.70 ± 0.90	1.20 ± 0.60	74.80
Mean	4.55	1.35	73.26

App.III-D. Lipid as % dry weight ± S.D. in the food and faeces and the respective monthly assimilation efficiency (%) calculated using ash as a marker.

	FOOD	FAECES	ASSIMILATION EFFICIENCY
October	3.5 ± 2.3	5.2 ± 2.0	-47.3
November	4.1 ± 1.8	5.0 ± 1.9	3.7
December	7.3 ± 1.3	7.4 ± 2.9	33.1
January	5.5 ± 2.5	6.0 ± 2.3	7.7
February	3.6 ± 2.2	3.6 ± 1.6	4.1
March	5.4 ± 2.2	5.3 ± 2.8	38.0
April	3.9 ± 2.0	5.1 ± 2.8	-3.9
May	4.1 ± 3.0	3.9 ± 1.5	9.8
June	6.1 ± 1.6	6.1 ± 2.0	43.5
July	3.9 ± 1.1	4.4 ± 1.4	17.7
August	7.7 ± 2.0	8.3 ± 1.2	23.2
September	8.4 ± 2.1	7.5 ± 1.9	30.1
Mean	5.32	5.65	13.3

App.III-E. Carbohydrate as % dry weight ± S.D. in the food and faeces and the respective monthly assimilation efficiency (%) calculated using ash a marker.

	FOOD	FAECES	ASSIMILATION EFFICIENCY
October	13.9 ± 3.5	11.9 ± 2.5	15.6
November	14.4 ± 4.2	12.6 ± 2.8	30.7
December	30.6 ± 3.4	26.1 ± 2.9	43.7
January	21.9 ± 3.9	20.5 ± 2.6	20.2
February	22.5 ± 4.1	17.7 ± 1.9	23.5
March	21.6 ± 3.3	14.3 ± 3.9	57.5
April	24.9 ± 4.7	20.6 ± 2.7	35.1
May	20.0 ± 8.1	17.3 ± 5.0	18.9
June	24.1 ± 5.4	10.9 ± 3.1	74.4
July	23.1 ± 8.0	14.1 ± 3.7	53.6
August	23.3 ± 3.0	13.3 ± 2.4	59.5
September	17.0 ± 7.6	13.9 ± 4.2	36.4
Mean	21.52	16.10	39.1

App.III-F. Different nutrients of each month as % AFDW ± S.D. including the unidentified component.

	PROTEIN AS % AFDW	LIPID AS % AFDW	CARBOHYDRATE AS % AFDW	UNIDENTIFIED COMP. % AFDW
October	7.9 ± 1.8	9.1 ± 5.6	38.1 ± 12.8	44.7
November	5.9 ± 1.0	6.7 ± 2.4	22.7 ± 6.2	64.7
December	8.5 ± 1.1	9.9 ± 1.4	41.3 ± 5.3	40.3
January	7.1 ± 1.2	8.7 ± 2.5	33.5 ± 5.6	50.8
February	6.0 ± 0.6	7.1 ± 4.1	44.2 ± 7.1	42.6
March	7.6 ± 0.9	8.5 ± 3.5	34.1 ± 5.7	49.8
April	7.7 ± 2.1	6.4 ± 3.2	41.9 ± 8.0	44.0
May	8.8 ± 1.5	7.9 ± 5.2	44.2 ± 8.0	39.1
June	7.7 ± 1.2	10.4 ± 3.1	40.4 ± 5.5	41.5
July	16.7 ± 2.9	8.1 ± 2.7	45.1 ± 9.1	30.2
August	8.4 ± 1.6	15.5 ± 4.5	46.7 ± 5.5	29.4
September	8.1 ± 1.5	17.8 ± 4.3	36.7 ± 13.9	37.4
Mean	8.4 + 2.8	9.7 + 3.5	39.1 + 6.7	42.9

App.III-G. Assimilation efficiency (%) of different nutrients and energy calculated for each month using ash as a marker.

	ORGANIC	PROTEIN	LIPID	CARBOHY-DRATE	ENERGY
October	3.8	65.7	-47.3	15.6	3.2
November	32.6	80.3	3.7	30.7	31.7
December	37.2	81.8	33.1	43.7	37.9
January	22.8	66.4	7.7	20.2	25.0
February	5.4	37.1	4.1	23.5	6.3
March	55.8	77.5	38.0	57.5	58.0
April	36.0	76.6	-3.9	35.1	36.8
May	14.1	73.4	9.8	18.9	16.2
June	72.1	93.7	43.5	74.4	72.1*
July	54.7	90.5	17.7	53.6	54.7*
August	58.8	65.4	23.2	59.5	58.8*
September	46.8	74.8	30.1	36.4	46.8*
Mean	36.7	73.3	13.3	39.1	37.3

* values taken from total organic matter assimilation.

App.III-H. Assimilation efficiency (%) of different nutrients including energy calculated for three months (May, August and November) using three different indigenous markers, ash,HRA, and HROM. AUG = August, NOV = November

		ORGANIC	PROTEIN	CARBOHY-DRATE	LIPID	ENERGY
	Ash	14.1	73.4	18.9	9.8	16.2
MAY	HROM	23.8	76.3	28.1	19.7	25.7
	HRA	4.7	70.5	9.9	-0.3	7.0
	Ash	58.8	65.4	59.5	23.2	N.D.
AUG	HROM	31.8	42.8	33.1	-26.9	N.D.
	HRA	57.9	65.6	58.7	21.6	N.D.
	Ash	32.6	80.3	30.7	-1.5	31.7
NOV	HROM	14.4	75.0	12.0	-22.2	13.3
	HRA	33.2	80.5	31.2	4.6	32.3

N.D. not determined.

App.III-I. Fulton's condition factor for each sex (monthly mean ± S.D.). n is sample size.

	MALE	FEMALE	* MALE + FEMALE (n = 40)
October	1.8 ± 0.2 n = 80	1.95 ± 0.33 n = 21	1.88 ± 0.27
November	1.97 ± 0.27 n = 53	1.99 ± 0.17 n = 25	1.94 ± 0.18
December	1.95 ± 0.11 n = 46	1.94 ± 0.11 n = 24	1.95 ± 0.10
January	1.95 ± 0.17 n = 47	1.91 ± 0.12 n = 26	1.95 ± 0.14
February	1.89 ± 0.10 n = 45	1.93 ± 0.20 n = 25	1.91 ± 0.16
March	1.86 ± 0.10 n = 35	1.80 ± 0.20 n = 37	1.83 ± 0.20
April	1.71 ± 0.28 n = 34	1.71 ± 0.25 n = 39	1.67 ± 0.25
May	1.90 ± 0.17 n = 72	1.91 ± 0.22 n = 63	1.88 ± 0.16
June	1.92 ± 0.14 n = 39	1.91 ± 0.12 n = 37	1.93 ± 0.11
July	1.95 ± 0.16 n = 31	1.92 ± 0.13 n = 39	1.93 ± 0.13
August	1.91 ± 0.16 n = 37	1.93 ± 0.16 n = 29	1.89 ± 0.16
September	1.90 ± 0.23 n = 48	1.84 ± 0.11 n = 28	1.90 ± 0.24

* 40 fish (20 from each sex) were randomly selected to test the difference in the condition of fish between months.

App.III-J. Mean monthly relative condition factor for each sex ± S.D.. n = sample size.

	MALE	FEMALE
October	0.95 ± 0.09	1.00 ± 0.18
	n = 80	n = 21
November	1.05 ± 0.13	1.09 ± 0.08
	n = 53	n = 25
December	1.04 ± 0.06	1.09 ± 0.06
	n = 46	n = 24
January	1.04 ± 0.07	1.04 ± 0.08
	n = 47	n = 26
February	0.99 ± 0.05	0.77 ± 0.27
	n = 45	n = 25
March	0.98 ± 0.05	0.89 ± 0.18
	n = 35	n = 37
April	0.91 ± 0.15	0.92 ± 0.12
	n = 34	n = 39
May	1.00 ± 0.09	1.02 ± 0.13
	n = 72	n = 63
June	1.02 ± 0.07	1.04 ± 0.07
	n = 39	n = 37
July	1.03 ± 0.08	1.03 ± 0.08
	n = 31	n = 39
August	1.02 ± 0.09	1.04 ± 0.11
	n = 37	n = 29
September	1.00 ± 0.12	0.94 ± 0.08
	n = 48	n = 28

App.III-K. Food quality (mg digestible protein/ KJ digestible energy) ± S.D.. P:E ratio = protein energy ratio. n = sample size.

MONTH	P:E RATIO	n
October	117.0 ± 39.6	12
November	10.2 ± 2.1	15
December	11.6 ± 2.1	14
January	11.0 ± 2.1	14
February	25.5 ± 11.1	14
March	6.0 ± 1.3	13
April	9.9 ± 2.6	14
May	25.9 ± 4.7	13
June	6.7 ± 1.3	14
July	19.5 ± 4.7	14
August	6.6 ± 1.6	13
September	8.3 ± 1.7	14

App.III-L. Concentrations (ug/l) of different forms of inorganic nitrogen and ortho-phosphate of Lake Ziway (Oct.'88 - Sep.'89). TIN = total inorganic nitrogen.

	NO_2+ NO_3-N (ug/l)	NH_3/NH_4^+-N (ug/l)	TIN (ug/l)	$PO_4^=$-P (ug/l)
October	1.0	8.0	9.0	N.D.
November	2.0	64.0	66.0	N.D.
December	1.0	44.0	45	N.D.
January	6.0	105.0	111.0	N.D.
February	2.0	9.0	11.0	N.D.
March	4.0	7.0	11.0	129.0
April	4.5	86.0	90.5	120.0
May	4.8	2.0	6.8	280.0
June	5.0	15.0	20.0	140.0
July	3.5	15.0	18.5	60.0
August	6.0	147.0	153.0	56.0
September	17.0	48.0	65.0	65.0

N.D. not determined.

VII- REFERENCES

Amblard, C., and G. Bourdier. 1988. Evidence for dial changes in adenine nucleotides, fatty acids contents and primary productivity in Lacustrine phytoplankton. Arch. Hydrobiol. 113(1): 1-14.

Amha, B., and R.B. Wood. 1982. Limnological aspects of an algal bloom on Lake Chamo, Gamo Gofa Administrative region of Ethiopia in 1978. Sinet: Ethiop. J. Sci. 5: 1-19.

Anderson, R.O., and S.J. Gutreuter. 1983. Length, Weight, and Associated Structural Indices, In: Fisheries Techniques, (L.A. Nielsen and D.L. Johnson, eds.), pp 283-300. American Fisheries Society, Bethesda, Maryland.

Balarin, J.D., and J. Hatton. 1979. Tilapia: A Guide to Their Biology and Culture in Africa. University of Stirling, Scotland. 174pp.

Beamish, F.W.H. 1972. Ration size and digestion in large mouth bass (Micropterus salmonides). Can. J. Zool. 50: 153-164.

Bowen, S.H. 1976. Mechanism for digestion of detrital bacteria by cichlid fish Sarotherodon mossambicus (Peter). Nature 260: 137-139.

Bowen, S.H. 1978. Chromic acid in assimilation studies - A caution. Trans. Am. Fish. Soc. 107(5): 755-756.

Bowen, S.H. 1979. A nutritional constraint in detritivory by fishes: the stunted population of Sarotherodon mossambicus in Lake Sibaya, South Africa. Ecol. Monogr. 49: 17-31.

Bowen, S.H. 1980. Detrital non-protein amino acids are the key to rapid growth of Tilapia in Lake Valencia, Venezuela. Science 207: 1216-1218.

Bowen, S.H. 1981. Digestion and assimilation of periphytic detrital aggregate by Tilapia mossambica. Trans. Am. Fish. Soc. 110: 239-245.

Bowen, S.H. 1982. Feeding, digestion and growth of Tilapias: some qualitative considerations, In: The Biology and Culture of Tilapia, (R.S.V. Pullin and R.H. Lowe-McConnell, eds.), pp 141-156. Manilla, Philippines. ICLARM.

Bowen, S.H. 1983. Detritivory in neotropical fish communities. Environ. Biol. Fish 9: 137-144.

Bowen, S.H. 1987. Composition and nutritional value of detritus, pages 192-216. In: Detritus and Microbial Ecology in Aquaculture, D.J.W. Moriarty and R.S.V. Pullin (eds.). ICLARM, Manilla, Philippines.

Bowen, S.H. 1988. Detritivory and Herbivory, In: Biology and Ecology of African Fresh water Fishes, (C. Leveque, M.N. Bruton, G. Sentongo, eds.), pp 243-247. Paris, France. ORSTOM.

Bowen, S.H. (in press). Cost-Benefit considerations for diets of primary consumer fishes.

Boyd, C.E. 1970. Amino acid, protein, and caloric content of vascular aquatic macrophytes. Ecology 51: 902-906.

Boyd, C.E. 1973. Amino acid composition of fresh water algae. Arch. Hydrobiol. 72: 1-9.

Boyd, C.E., and C.P. Goodyear. 1971. Nutritive quality of food in ecological systems. Arch. Hydrobiol. 69: 256-270.

Bromley, P.J. 1987. The effects of food type, meal size and body weight on digestion and gastric evacuation in turbot, Scophthalmus maximus L. J. Fish Biol. 30: 501-512.

Buddington, R.K. 1979. Digestion of an aquatic macrophyte by Tilapia zilli (Grevais). J. Fish Biol. 15: 449-455.

Buddington, R.K. 1980. Hydrolysis-resistant organic matter as a reference for measurement of fish digestive efficiency. Trans. Am. Fish. Soc. 109: 653-656.

Caramichael, W.W., Y. Min-Yuan, H. Zhen-Rong, H. Jia-Wan and Y. Jia-Lu. 1988. Occurrence of the toxic cyanobacterium (blue-green algae) Microcystis aeruginosa in Central China. Arch. Hydrobiol. 114(1): 21-30.

Cherviniski, J. 1982. Environmental physiology of Tilapias, In: The Biology and Culture of Tilapia, (R.S.V. Pullin and R.H. Lowe-McConnell, eds.), pp 119-128. Manilla, Philippines. ICLARM.

Conover, R.J. 1966. Assimilation of organic matter by zooplankton. Limnol. Oceanog. 11: 338-345

Daniel, G. 1977. Aspects of climate and Water Budget in Ethiopia. Addis Ababa: Addis Ababa University Press. 71pp.

Demeke, K. 1985. Variation in phytoplankton primary production in relation to light and nutrients in lake Awassa. M.Sc. thesis. Addis Ababa: Addis Ababa University. 112pp.

De Moor, F.C, and W.E. Scott. 1985. Digestion of Microcystis aeruginosa by Oreochromis mossambicus. J. Limno. Soc. Sth. Afr. 11: 14-19.

De Silva, S.S. 1985. Body condition and nutritional ecology of Oreochromis mossambicus (Pisces: Cichlidae) populations of man-made lakes in Sri Lanka. J. Fish Biol. 27: 621-633.

De Silva, S.S., and A.A. Owoyemi. 1983. Effect of dietary quality on the gastric evacuation and intestinal passage in Sarotherodon mossambicus (Peters) fry. J. Fish Biol. 23: 347-355.

De Silva, S.S., and M.K. Perera. 1983. Digestibility of an aquatic macrophyte by the cichlid Etroplus suratensis (Bloch) with observations on the relative merits of three indigenous components as markers and daily changes in protein digestibility. J. Fish Biol. 23: 675-684.

De Silva, S.S., and M.K. Perera. 1985. Effects of dietary protein level on growth, food conversion, and protein use in young Tilapia nilotica at four salinities. Trans. Am. Fish. Soc. 114: 584-589.

De Silva, S.S., M.K. Perera, and P. Maitipe. 1984. The composition, nutritional status and digestibility of the diets of Sarotherodon mossambicus from man-made lakes in Sri Lanka. Env. Biol. Fish. 11(3): 205-219.

Dunn, I.G. 1972. Ecological studies on the fish of Lake George, Uganda. Ph.D. thesis. Univeristy of London.

Edwards, P. 1980. The production of microalgae on human wastes and their harvest by herbivorous fish, In: Algae Biomass: production and use. (G. Shelef and C.J. Soeder, eds.), pp 191-203. North-Holland Biomedical press.

Elizabeth, K. 1987. A seasonal study on the species composition and phytoplankton biomass in Lake Awassa, Ethiopia. M.Sc. thesis. Addis Ababa: Addis Ababa University. 70pp.

Fish, G.R. 1955. The food of Tilapia in East Africa. Uganda J. 19: 85-89.

Fish, G.R. 1960. The comparative activity of some digestive enzymes in the alimentary canal of Tilapia and Perch. Hydrobiologia. 15: 161-178.

Folin, O., and W. Denis. 1912. Tyrosine in proteins as determined by a new colorimetric method. J. Biol. Chem. 12: 245-251.

Fryer, G. ,and T.D. Iles. 1972. The cichlid Fishes of the Great Lakes of Africa. Oliver and Boyd, Edinburgh. 641pp.

George, T.T. 1976. Introduction and transplantation of cultivable species into Africa. FAO/CIFA Tech. Pap, 4(suppl.1): 407-437.

Gerking, S.D. 1952. The protein metabolism of sunfishes of different ages. Physiol. Zool. 25: 358-372.

Getachew, T. 1987. Food, nutrition and digestive efficiency in Oreochromis niloticus Linn. (Pisces: Cichlidae) in Lake Awassa, Ethiopia. Ph.D. thesis. Waterloo: University of Waterloo. 109pp.

Getachew, T. 1989a. Stomach pH, feeding rhythm and ingestion rate in Oreochromis niloticus L. (Pisces: Cichlidae) in Lake Awassa, Ethiopia. Hydrobiologia 174: 43-48.

Getachew, T. 1989b. The food habits of an herbivorous fish (Oreochromis niloticus Linn.) in Lake Awassa, Ethiopia. Hydrobiologia 174: 195-200.

Getaneh, W., and M. Getaneh. 1979. Breeding period and fecundity of Tilapia nilotica L. in Lake Zwai. Eth. J. of Agr. Sci. 1: 13-21.

Gibson, C.E. 1978. Field and laboratory observations on the temporal and spatial variation of carbohydrate content in planktonic blue-green algae in Lough Neagh, Northern Ireland. J. Ecol. 66 : 97-115.

Girma, T. 1988. A seasonal study on the phytoplankton primary production in relation to light and nutrients in Lake Ziway, Ethiopia. M.Sc. thesis. Addis Ababa: Addis Ababa University. 61pp.

Golterman, H.L., R.S. Clymo, and M.A.M. Ohstand. 1978. Methods for physical and chemical analysis of fresh water. 2nd ed. IBP Handbook No. 8. Oxford: Blackwell Scientific Publications. 213pp.

Grove, A.T., F.A. Street, and A.S. Goudie. 1975. Former lake levels and climatic changes in the rift valley of Southern Ethiopia. Geogrl. J. 141(2): 177-202.

Haberland, E. 1963. Die Voelker Sued - Aethiopiens, 2, Teil 3-W. Kohlhammer Verlag.

Hanazato, T., and M. Yasuno. 1987. Evaluation of Microcystis as food for zooplankton in a eutrophic lake. Hydrobiologia 144: 251-259.

Hanley, F. 1987. The digestibility of food stuffs and the effects of feeding selectivity on digestibility determinations in Tilapia, Oreochromis niloticus (L). Aquaculture 66: 163-179.

Hofer, R., and F. Schiemer. 1983. Feeding ecology, assimilation efficiency and energetics of two herbivorous fishes Sarotherodon(Tilapia) mossambicus (Peters) and Puntius filamentosus (Cuv. et Val.), In: Limnology of Parakrama Samudra - Sri Lanka, (F. Schiemer, ed.), pp 155-164. The Hague. Dr. W. Junk Publishers.

Idyll, C.P. 1970. The Sea Against Hunger. Thomas Y. Cromwell Company. New York. 221pp.

Jordan, N.H., and F.H. hall. 1900. The digestibility of American feed stuffs. USDA Off. Exp. Stas. Bul.77.

Kassahun, W. 1982. Comparative limnology of lake Abijata and Lake Langano in relation to primary and secondary production. M.Sc. thesis. Addis ababa: Addis Ababa university. 112pp.

Kaushik, N.K., and H.B.N. Hynes. 1968. Experimental study on the role of autumn-shed leaves in aquatic environments. J. Ecol. 65: 229-243.

Ketema, A. 1986. The sedimentology of the diatomite bearing lacustrine deposits of Adami Tulu area, Arsi, Ethiopia. M.Sc. thesis. Addis Ababa: Addis Ababa University. 110pp.

Kirilenko, N.S., G.B. Melinkov, L.R. Grinberg, and N.I. Nazimirova. 1975. The digestibility of the crude protein and neutral fat of some microalgae by Tilapia mossambica Peters. J. Ichthyol. 15: 151-155.

Le cren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in perch (Percha fluviatilis). J. Anim. Ecol. 20: 201-209.

Lobel, P.S. 1981. Trophic biology of herbivorous reef fishes: alimentary pH and digestive capabilities. J. Fish Biol. 19: 365-397.

Lobel, P.S., and J.C. Ogden. 1981. Foraging by the herbivorous parrot fish Sparisoma radians. Mar. Biol. 64: 173-183.

Lowe-McConnell, R.H. 1975. Fish Communities in Tropical Fresh waters. Longman, New York. 337pp.

Lowe-McConnell, R.H. 1982. Tilapias in Fish Communities, In: The Biology and Culture of Tilapias, (R.S.V. Pullin and R.H. Lowe- McConnell, eds.), pp 83-113. Manilla, Philippines. ICLARM.

Lowe-McConnell, R.H. 1987. Ecological Studies in Tropical Fish Communities. Cambridge University Press. Cambridge. 382pp.

Lowry, O.H., N.J. Rosenbrough, A.R. Farr, and R.J. Randall. 1951. Protein measurements with folin phenol reagent. J. Biol. Chem. 193: 265-275.

Mackereth, F.J.H., J.Heron, and J.F. Talling. 1978. Water Analysis: Some revised methods for limnologists. FBA Scientific Publications No. 36. 120pp.

Maitipe, O., and S.S. De Silva. 1985. Switches between zoophagy, phytophagy and detritivory of Sarotherodon mossambicus (Peters) populations in twelve man-made Sri Lanka lakes. J. Fish Biol. 26: 49-61.

Makin, M.J., J.J. Kingham, A.E. Wadden, C.J. Birchall, and T. Tamene. 1975. Development Projects in The Southern Rift Valley of Ethiopia. Land Resource study 21. Land Resources Division. Ministry of Overseas Development, England.

Marshall, N.B. 1965. The Life of Fishes. Weidfeld and Nicolson. London. 402pp.

Mattson, W.J. 1980. Herbivory in relation to plant nitrogen content. Ann. Rev. Ecol. Syst. 11: 119-161.

McBay, L.G. 1961. The biology of Tilapia nilotica Linneaus. Proceedings of the fifteenth annual conference, South eastern association of Game and Fish Commissioners, October 22-25, 1961, pp 208-218.

Mohr, P.A. 1962. The Ethiopian rift system. Bull. Goephys. Obs. Addis Ababa. 3: 33-62.

Montgomery, M.L., and S.D. Gerking. 1980. Marine microalgae as foods for fishes: an evaluation of potential food quality. Env. Biol. Fish 5: 143-153.

Moriarty, D.J.W. 1973. The physiology of digestion of blue-green algae in the cichlid fish, Tilapia nilotica. J. Zool. Lond. 171: 25-39.

Moriarty, C.M., and D.J.W. Moriarty. 1973a. Quantitative estimation of the daily ingestion of phytoplankton by Tilapia nilotica and Haplochromis nigripinnis in Lake George, Uganda. J. Zool. Lond. 171: 15-23.

Schneider, B.H., and W.B. Flatt. 1975. The Evaluation of Feeds through Digestibility Experiments. The University of Georgia Press, Athens. 432pp.

Schroder, R. 1984. An attempt to estimate the fish stock and sustainable yield of Lake Ziway and Lake Abaya, Ethiopian Rift Valley. Arch. Hydrobiol. Suppl. Bd. 69: 411-441.

Semeneh, B. 1988. Zooplankton composition and seasonal dynamics in Lake Ziway, Ethiopia. M.Sc. thesis. Addis Ababa: Addis Ababa University. 121pp.

Siddiqui, A.Q. 1977. Reproductive biology, length-weight relationship and relative condition of Tilapia leucosticta (Trewavas) in Lake Naivasha, Kenya. J. Fish Biol. 10: 251-260.

Sokal, R.A., and F.J. Rohlf. 1981. Biometry 2nd edn. W.H. Freeman and Company. New York. 859pp.

Stickney, R.R., and S.E. Shumway. 1974. Occurrence of cellulase activity in the stomachs of fishes. J. Fish Biol. 6: 779-790.

Strickland, J.D.H., and T.R. Parsons. 1968. A Practical Handbook of Sea water Analysis. Fish. Res. Bd. Can. 310pp.

Teshima, S., A. Kanazawa, and S. koshio. 1987. Effects of feeding rate, fish size, and dietary protein and cellulose levels on the growth of tilapia nilotica. Mem. Fac. Fish 36(1): 7-15.

Teshima, S., A. Kanazawa, and Y. Uchiyama. 1986. Effect of several protein sources and other factors on the growth of Tilapia nilotica. Nippon Suisan Gakkaaishi 52: 525-530.

Trewavas, E. 1982. Taxonomy and speciation, In; The Biology and Culture of Tilapias, (R.S.V. Pullin and R.H. Lowe-McConnell, eds.), pp 1-13. Manilla, Philippines. ICLARM.

Tsegaye, M-A. 1988. A seasonal study on the species composition and phytoplankton biomass in Lake Ziway, Ethiopia. M.Sc. thesis. Addis Ababa: Addis Ababa University. 72pp.

Von Damm, K.L., and J.M. Edmond. 1984. Reverse weathering in the closed-basin lakes of the Ethiopian rift. Am. J. Sci. 284: 835-862.

Wetzel, R.G. 1983. Limnology 2nd edn. Saunders College Publishing. Philadelphia. 767pp.

Wood, R.B., M.V. Prosser, and R.M. Baxter. 1978. Optical characteristics of the rift valley lakes, Ethiopia. Sinet: Ethiop. J. Sci. 1(2): 73-85.

Zenebe, T. 1988. Studies on some aspects of the biology of Oreochromis niloticus (L) (Pisces: Cichlidae) in Lake Ziway, Ethiopia. M.Sc. thesis. Addis Ababa: Addis Ababa University. 78pp.