

FEEDING HABITS OF THE CATFISH *SYNODONTIS SCHALL* (BLOCH & SCHNEIDER) (PISCES: MOCHOKIDAE) WITH EMPHASIS ON ITS SCALE-EATING HABITS IN LAKE CHAMO, ETHIOPIA

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ABSTRACT: *Synodontis schall* (Bloch & Schneider) is an abundant fish in Lake Chamo, but its feeding ecology is not well-known to guide its management. Diet composition and ontogenetic diet shift were investigated from stomach contents of 545 fish from August 1998 to February 2000. Volumetrically, the dominant food items were zooplankton, fish scales and macrophytes. Zooplankton occurred in 83.3% of the stomachs and accounted for 26.5% of the total volume. Fish scales occurred in 35.0% of the stomachs and accounted for 30.6% of the total volume of food. Macrophytes occurred in 9.8% of the stomachs and contributed 19.4% of the total volume of food eaten. Insects occurred in 37.3% of the stomachs and contributed 8.3% of the total volume of food eaten. Fish fry occurred in 13.7% of the stomachs and constituted 10.9% of the total volume of food consumed. Diatoms, zooplankton and insects constituted 89.8% of the volume of food eaten by juveniles, but their importance declined with the size of fish. Importance of fish scales increased with size of fish. From these results, it is evident that zooplankton and insects were the most important food items of juveniles while fish scales, fish fry and macrophytes were the most important food items of adults. The information obtained from this study allows us to determine the effect *Synodontis* has on other organisms through competition and predation. This knowledge can be used in management of *Synodontis* fisheries by determining the prey type of the species and how the changing biological and physical conditions in the lake affect them.

Key words/phrases: Ethiopia, Feeding, Lake Chamo, *Synodontis schall*.

INTRODUCTION

The genus *Synodontis*, commonly referred to as squeaker or upside-down catfish, is widely distributed in African freshwaters ranging from the Nile basin, Chad, Niger and much of the West African region (Paugy and Roberts, 1992). The genus has over 112 species (Daget *et al.*, 1991) and some of the species are commercially important comprising up to 40% of

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the total landings by weight in some regions of Africa (Willoughby, 1974; Sanyanga, 1996). *Synodontis schall* (Bloch & Schneider) is the most tolerant species to adverse environmental conditions in the genus and it has the widest distribution in Africa (Lowe-McConnell, 1987). In Ethiopia, it is found in Lakes Abaya and Chamo in the south, the Baro River and its tributaries in the west and in the Wabe Shebele River in the southeast (Shibru Tedla, 1973; Paugy and Roberts, 1992; Golubtsov *et al.*, 1995). *S. schall* is not of any direct commercial importance in its contribution to the traditional fishery of Lake Chamo. However, it is ecologically important because it serves as the main prey of the commercially valuable catfish *Bagrus docmak* (Forsskål, 1775) (Hailu Anja and Seyoum Mengistou, 2001). It is one of the most abundant fish in both littoral and pelagic habitats of the lake. Local fishermen consider the species as a nuisance because often it is entangled in their gill nets and is very difficult to remove from the nets since it has long and serrated spines.

Various studies have been conducted on the feeding habits of *S. schall* in some African water bodies. Willoughby (1974) described it as omnivorous, feeding on insect nymph and larvae, fish eggs and detritus. Hickley and Bailey (1987) indicated the importance of fish, bivalves and snails in its diet. Ofori-Danson (1992) reported benthic macro-invertebrates and macrophytes as the major diet of the species and also pointed out the presence of small quantities of fish scales in the stomach contents from Kpong Headpond in Ghana. Bishai and Gideiri (1965) also reported the presence of fish scales in the stomach contents of *S. schall* in the Nile River at Khartoum.

Scale-eating habits have been reported in East African freshwater cichlids of the genera *Corematodus*, *Plecodus*, *Perisodus*, *Genyochromis* (Marlier and Leleup, 1954; Fryer *et al.*, 1955; Fryer and Iles, 1972), South American freshwater characoids of genera *Exodon*, *Roiboides*, *Roeboexodon*, *Probolodus* and *Cataprion* (Roberts, 1970) and in South African coastal thornfish of the genus *Terapon* (Whitfield and Blaber, 1978). Exploitation of this ecological niche and the mechanisms by which this species feeds on fish scales have not been reported in the genus *Synodontis*.

So far no published work is available on the biology and ecology of *S. schall* in Lake Chamo. Bizualem Gutema (2011) studied the feeding habit and heavy metal concentration of *S. schall* in Lake Abaya. The aim of this work was to study diet composition and feeding habits of the species in Lake Chamo with special emphasis on its scale-eating habit.

MATERIALS AND METHODS

Description of the study area

Lake Chamo ($5^{\circ}42' - 5^{\circ}58' \text{ N}$; $37^{\circ}27' - 37^{\circ}38' \text{ E}$) has a surface area of approximately 551 km^2 , a maximum depth of 16 m and lies at an altitude of 1,108 m (Amha Belay and Wood, 1982). The lake lies to the east of the Precambrian block of the Amaro Mountains within the less intensely faulted basin (Mohr, 1962). The surrounding region receives two rainy seasons per year, March- May (heavy rains) and September-October (little rains). The mean annual rainfall of the area for the period 1982- 2009 was 881 mm (Ethiopian Meteorological Agency, unpublished data). The main affluent of the lake is Kulfo River, which flows in at the north end of the lake and the less important feeders are Sile and Sago Rivers entering from the west. During the past three decades, the water level of the lake has declined considerably and this has resulted in significant shrinkage of the lake's surface area (personal observation).

The ichthyofauna of Lake Chamo, and also that of Lake Abaya, is Soudanian species (Beadle, 1981). The fish species are more diverse than the other rift valley lakes of the country, as a result of the northward migration of the Soudanian species when the lake was in contact with the Nile system 7,000 years ago (Golubtsov and Redeat Habteselassie, 2010). There are 18 fish species in Lake Chamo and the inflowing rivers belonging to 9 families and 12 genera. The landings of the commercial fishery are mainly composed of *Oreochromis niloticus* (L.), *Labeo horie* (Heckel), *Lates niloticus* (L.), *Bagrus docmak* (Forsskål) and *Clarias gariepinus* (Burchell).

Sampling

Monthly fish samples were obtained from three sites in the pelagic area of the lake (Fig. 1c) from August 1998 to February 2000 using a fleet of gill nets (60 mm, 80 mm, 100 mm and 120 mm stretched mesh sizes) in the pelagic area of the lake. The gill nets were usually set 3-5 km from the shoreline of the lake late in the afternoon at around 5.00 pm and lifted early the next morning around 6.00 am local time. Beach seine (25 x 4 m) and small hook and line gear (the hooks were 4 cm in length) were also used to capture juvenile fish in the shallow littoral areas. Fork lengths (FL) of all fish were measured to the nearest millimetre and total weights were taken to the nearest gram immediately after capture. Stomach samples were put in plastic containers, preserved in 5% formalin solution, and transported to the laboratory for further analysis.

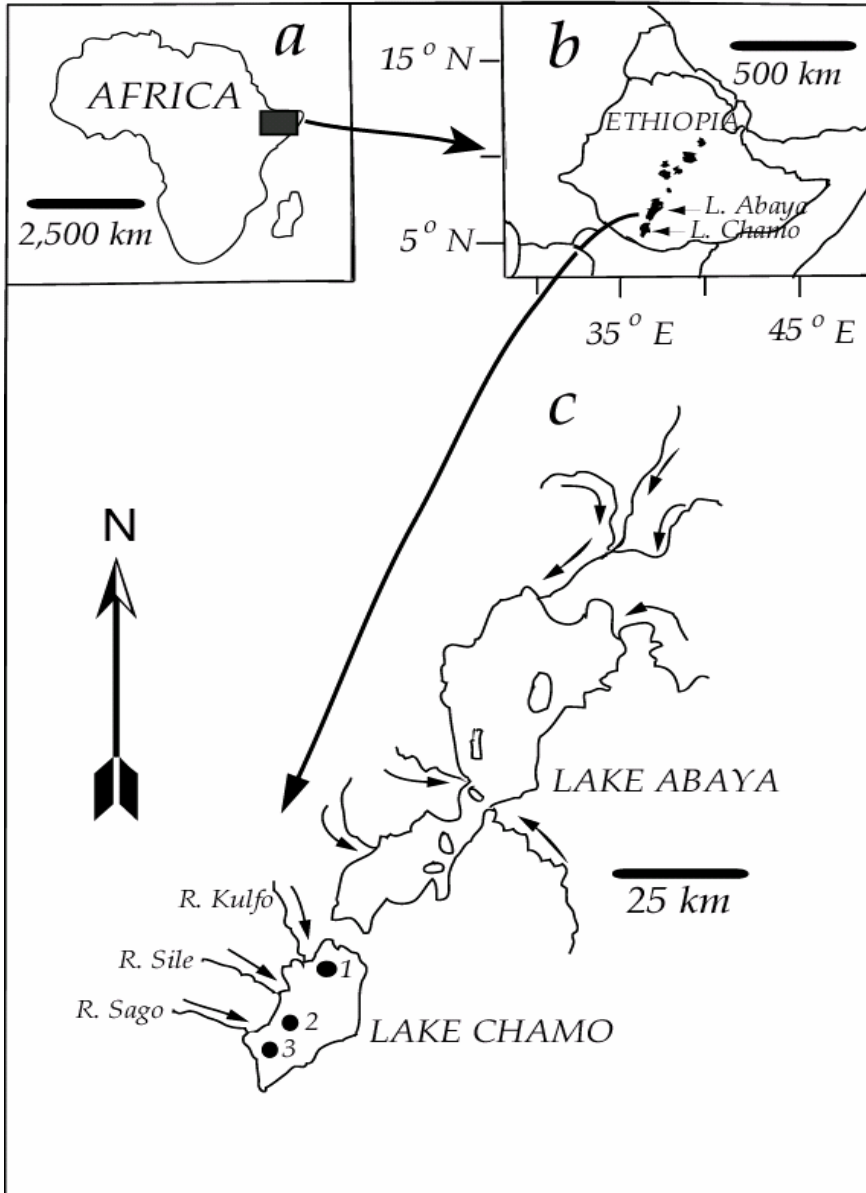


Fig. 1. Map of Africa with the relative position of the Horn of Africa highlighted (a) map of Ethiopia with the relative position of the Ethiopian rift valley lakes indicated (b) and the southern rift valley lakes of Ethiopia (Lakes Abaya and Chamo); the sampling stations in Lake Chamo indicated (c) (1-Deset, 2-Bedena, 3-Bole).

Stomach content analysis

Identification of stomach contents was done visually in case of large food items, but a dissecting microscope was used for smaller organisms. The relative importance of food items was investigated using frequency of occurrence, the percentage composition by number and gravimetric methods of analysis. In frequency of occurrence method, the number of stomachs in which a given category of food item occurs is expressed as a percentage of the total number of non-empty stomachs examined (Windell and Bowen, 1978). This method provides information on the proportion of the population that fed on that particular food item.

In numerical analysis the number of food items of a given type that were found in all samples examined was expressed as a percentage of all food items (Windell and Bowen, 1978). This estimated the relative abundance of that food item in the diet. In volumetric analysis, food items that were found in the stomachs were sorted into different taxonomic categories and the volume of items in each category was measured (Bowen, 1983). The relative importance of a food category was then expressed as a percentage of all the categories of food items present in the samples.

If fish scales were found in the stomachs, they were counted, their volume was measured and the maximum width of each scale was measured to the nearest millimetre. The mean diameter of scales found in each stomach was calculated by dividing the sum of the diameters by the number of scales present.

In assessing the importance of different food items at different size classes, the fish were categorized into six size classes (I: 10.0-14.9 cm, II: 15.0-19.9 cm, III: 20.0-24.9 cm, IV: 25.0-29.9 cm, V: 30.0-34.9 cm and VI: 35.0-39.9 cm) and the total volume of food in each size class was determined. Volumetric contribution of each category of food items was then expressed as a percentage of total volume of food consumed in each size class.

An index of relative importance (IRI) value for each food item was calculated as follows:

$$\text{IRI} = \%F \times (\%N + \%V) \quad (1)$$

where %N is the number of each prey item as a percentage of the total number of prey items identified, %V is the percentage in volume of each prey item and %F is the frequency of occurrence for each prey item in the total number of stomachs examined. This method emphasizes the importance of small and numerous food items, such as diatoms and

zooplankton. Moreover, values cannot be given when the diet contains significant proportion of plant material or detritus, categories that do not include discrete, individual prey. The IRI of each prey item was standardized to %IRI:

$$\%IRI = 100 \times IRI_i / \sum IRI_i \quad (2)$$

Dietary overlap between different length-classes was calculated as percentage overlap using Schoener Diet Overlap Index (SDOI) (Schoener, 1968; Wallace, 1981), based on the formula:

$$\alpha = 1 - 0.5 \left(\sum_{i=1}^n |P_{ai} - P_{bi}| \right) \quad (3)$$

where α is percentage overlap, SDOI, between size group a and b , P_{ai} and P_{bi} are proportions of food category (type) i used by size group a and b , and n is the total number of food categories. Diet overlap in the index is generally considered to be biologically significant when α value exceeds 0.60 (Zaret and Rand, 1971; Mathur, 1977).

RESULTS

Description of the diet

Based on stomach contents of 545 *S. schall* specimens that ranged in length from 10.2 to 38.3 cm FL and 63 to 1170 g TW numerical analysis, frequency of occurrence and volumetric methods revealed zooplankton, fish scales and macrophytes as the dominant dietary items (Table 1). Since macrophytes are not countable, frequency of occurrence and volumetric methods of analyses were employed for this food item. Other food organisms that were ingested relatively frequently were insects, fish fry and fish eggs (Fig. 2).

Table 1. Summary of the diet of 545 *S. schall* in Lake Chamo as described by percentage frequency of occurrence (%F), percentage composition by number (%N), percentage volume (%V) and the corresponding IRI and %IRI values of the various food items.

Food items	%F	%N	%V	IRI	%IRI
Fish scales	35.0	1.6	30.6	1127.0	17.3
Copepoda	75.5	24.1	21.2	3420.2	52.5
Cladocera	76.5	9.5	5.0	1109.3	17.0
Rotifera	15.6	6.3	0.3	103.0	1.6
Fish	13.7	0.02	10.9	149.6	2.3
Fish eggs	3.8	1.5	2.6	15.6	0.2
Diptera	31.1	1.5	5.0	202.2	3.1
Odonata	6.2	0.03	1.5	9.5	0.2
Coleoptera	4.9	0.3	0.9	5.9	0.1
Other insects	7.7	0.2	0.9	8.5	0.1
Macrophytes	9.8	-	19.4	-	-
Diatoms	6.4	55.0	1.4	361.0	5.5

By the frequency of occurrence method, zooplankton accounted for 83.3% of all *S. schall* examined. Numerically zooplankton constituted 39.9% of the total number of food organisms. In the volumetric analysis, zooplankton accounted for 26.5% of the food consumed (Fig. 2). Among the crustaceans, Cyclopoid copepods (*Thermocyclops decipiens* Kiefer and *Mesocyclops ogunnus*) were the most important prey for *Synodontis*. Cladocerans (*Moina macrura* Kurz *Diaphanosoma exisum*, *Ceriodaphnia* sp.) were also relatively common in the diet of *S. schall*. Less notable zooplankton were rotifers (*Brachionus angularis* Gosse and *Keratella* sp.).

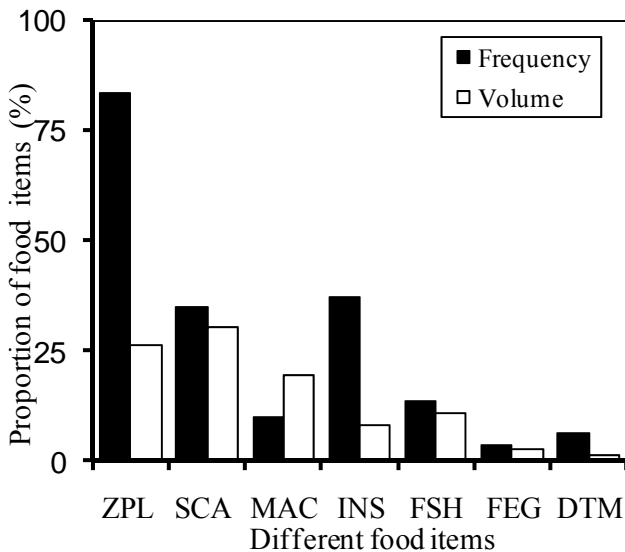


Fig. 2. Percentage frequency of occurrence and percentage volume of diet of *S. schall* in Lake Chamo (ZPL- Zooplankton, SCA- Scales, MAC- Macrophytes, INS- Insects, FSH- Fish, FEG- Fish eggs, DTM- Diatoms).

Fish scales contributed 1.6% of the total number of food items consumed, occurred in 35.0% of the stomachs examined and constituted 30.6% of the total volume of food items consumed (Table 1). The scales in most stomach contents came from three fish species, namely *L. horie*, *O. niloticus* and *L. niloticus*. A total of 3537 scales were found in all the stomach contents examined, with a mean number of 7.7 per stomach content and scale diameter of 5-24 mm. In one stomach of *Synodontis* (FL = 34.2 cm, TW = 770 g) 210 scales (7.2 ml) were found. Another fish (FL = 34.7 cm, TW = 690 g) consumed 188 (6.3 ml) scales. Shoots, roots and seeds of macrophytes occurred in 9.8% of the stomachs and contributed 19.4% of the total volume of food consumed (Table 1).

Insects occurred in 37.3% of the stomachs and constituted 1.7% of the total number of food items. Their volumetric contribution was 8.3% of the total volume of food items (Table 1, Fig. 2). Diptera (Chironomidae larvae) were by far the most important prey among insects (Table 1). Odonata and Coleoptera were also relatively common (Table 1). Other insects including Hemiptera, Ephemeroptera and Tricoptera were of less importance because they occurred less frequently and also contributed to lower number and volume of the food consumed (Table 1).

Fish fry (*O. niloticus*) occurred in 13.7% of the stomachs examined, accounted for 0.02% of the total number and contributed 10.9% of the total volume of food consumed (Table 1). Fish eggs occurred in 3.8% of the stomachs, constituted 1.5% of the total number and accounted for 2.6% of the total volume of food eaten (Table 1). Diatoms occurred in 6.4% of the stomachs and contributed 55.0% of the total number of food organisms (Table 1). Volumetrically, diatoms contributed 1.4% of the total volume of food eaten (Table 1).

Ontogenetic diet shift and scale-eating habit

The number of fish captured in each size class ranged from 40-174 (Fig. 3). There was clear evidence of ontogenetic diet shift within the size range of fish examined. Generally, importance of diatoms, zooplankton and insects declined as the size of fish increased. In 10.0-14.9 cm FL size class, zooplankton contributed 68.1% of the total weight of food consumed, but they contributed only 12.5% of the total volume of food consumed in 35.0-39.9 cm FL size class (Fig. 3). Insects constituted 22.0% of the total volume of food consumed by 10.0-14.9 cm FL, but their contribution declined sharply with the size of the fish and constituted only 3.8% of the total volume of food eaten by the 35.0-39.9 cm group (Fig. 3). Diatoms

constituted 7.1% of the total volume of food consumed in 10.0-14.9 cm FL size class, but their contribution declined to 2.2% of the total volume of food eaten by 20.0-24.9 cm FL size class (Fig. 3). No diatoms were consumed by fish greater than 25 cm FL size class (Fig. 3).

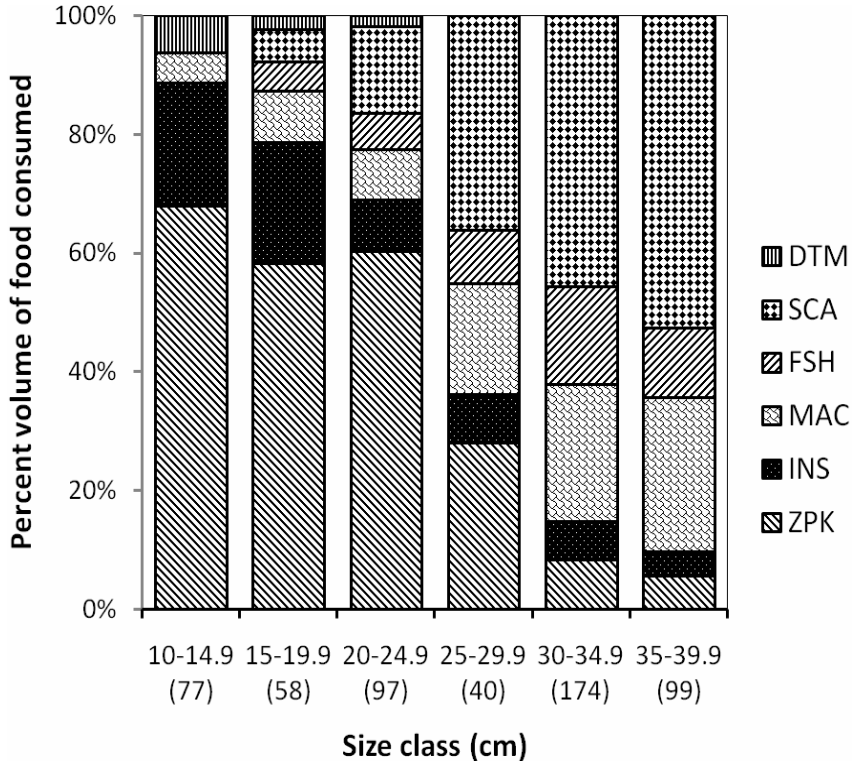


Fig. 3. Percentage by volume of different food items consumed at different size classes of *S. schall* in Lake Chamo. Numbers in parenthesis indicate number of fish sampled in each size class (ZPL - Zooplankton, SCA - Scales, MAC - Macrophytes, FSH - Fish, INS - Insects, FEG - Fish eggs, DTM - Diatoms).

On the other hand, the volume of fish scales, fish fry and macrophytes consumed by *S. schall* increased with size. No fish scales were consumed by 10.0-14.9 cm FL size class (Fig. 3). In 15.5-19.9 cm FL size class, fish scales contributed only 5.5% of the total volume of food eaten, but in 35.0-39.9 cm FL size class the contribution was 50.6% of the total volume eaten (Fig. 3). *S. schall* has developed dentition that enables it to remove scales from other fish. The lower jaw has elongated and closely placed comb-like teeth. The upper jaw has a broad band of short and file-like bony structures (Fig. 4). The comb-like teeth on the lower jaw are suitable to pick scales and

then by pressing them against the band of teeth on the upper jaw they can easily remove the scales from the body of other fish.

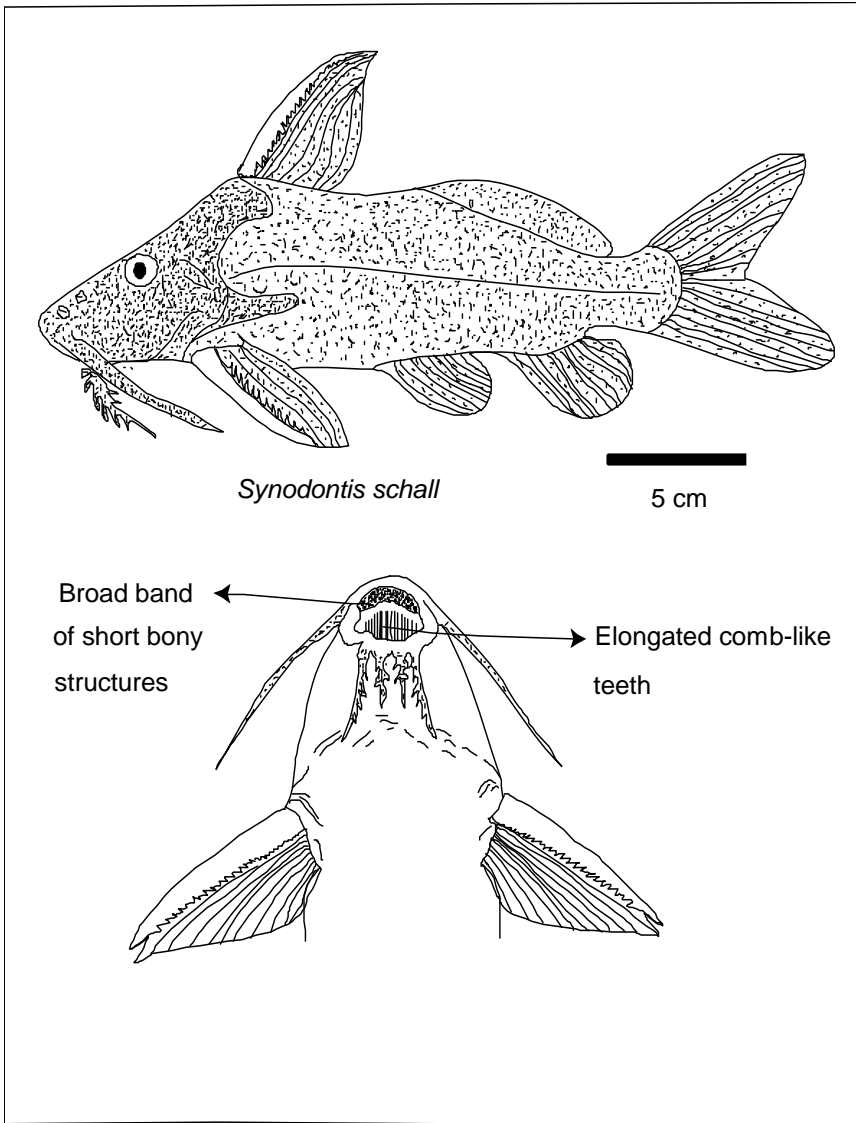


Fig. 4. Ventrally positioned mouth of *S. schall* with broad band of short bony structures on the upper jaw and elongated comb-like teeth on the lower jaw that are adapted for removing scales from other fish.

The importance of fish fry and plant materials also increased with fish size (Fig. 3). The presence of fish fry was strongly associated with macrophytes. Fish fry were not consumed by 10.0-14.9 cm FL size class. In 15.0-19.9 cm FL size class fish fry constituted 6.3% of the total volume of food eaten, but their contribution increased to 15.0% of the total volume of food eaten by 35.0-39.9 cm FL size class (Fig. 3). Macrophytes contributed 6.3% of the total volume of food consumed by 10.0-14.9 cm FL size class, but the contribution of macrophytes increased to 32.5% of the total volume of food consumed by 35.0-39.9 cm FL size class (Fig. 3).

%IRI is given for different food items in Table 1. Food items that resulted in high %IRI were copepoda (52.5%), cladocera (17.0%) and fish scales (17.3%). Diptera (Chironomidae larvae) and fish fry (*O. niloticus*) accounted for 3.1% and 2.3%, respectively (Table 1). Contributions of other food items were relatively low and accounted for the remaining 2.2% of the total index (Table 1).

There was no significant difference in the diets of individuals in the size classes I and II, I and III, II and III, III and IV, III and V, IV and V and V and VI (SDOI = 86.4%, 76.5%, 87.3%, 64.2%, 78.9, 73.4 and 90.8, respectively) (Table 2). Significant differences in the diets of individuals were observed in the size classes I and IV, I and V, I and VI, II and IV, II and V, II and VI, III and V and III and VI (SDOI = 45.7%, 20.6%, 14.3%, 54.3%, 33.2%, 27.7%, 43.1, 37.6, respectively) (Table 2).

DISCUSSION

The results of this study indicate that *S. schall* in Lake Chamo feeds on a variety of food items including zooplankton, fish scales, plant materials, fish fry, insect larvae, fish eggs and diatoms. Zooplankton, fish scales and macrophytes constituted the bulk of food consumed. But the importance of these food items changed with size of fish. Zooplankton and macro-invertebrates were the most important food items of juvenile *S. schall*, while fish scales and macrophytes were the most important food items of adults.

Various authors studying the feeding habits of *Synodontis* in different parts of Africa have reported the polyphagous nature of the genus. Willoughby (1974) studying the ecology of *Synodontis* in Lake Kanji (Nigeria) described *S. schall* as omnivorous feeding on insect nymph and larvae, fish eggs, and detritus. Hickley and Bailey (1987) studying *S. schall* in the Sudd swamps of the River Nile (Sudan) have pointed out the importance of detritus, benthic algae, macrophytes, benthic crustaceans, insects and fish in its diets. Ofori-Danson (1992) working on the ecology of some *Synodontis* species in

Kpong Headpond (Ghana) indicated the dominant food items of *S. schall* as detritus, insects, Oligochaeta, Nematoda and Hirudinea. Sanyanga (1998) studied the food composition and selectivity of *Synodontis zambezensis* in Lake Kariba and reported molluscivorous feeding habits. The species actively selected the pulmonate *Lymnaea natalensis* and chironomidae larvae in 59% and 30% of the cases, respectively (Sanyanga, 1998). Laléyé *et al.* (2006) studied the food and feeding habits of *S. schall* in Quémé River, Benin, and found out the main food items of the species to be phytoplankton, rotifers, insect larvae, crustaceans, mollusks and nematodes. Studies conducted on the food and feeding habits of other *Synodontis* species from different parts of Africa also indicate the polyphagous feeding habits: *Synodontis comoensis* (Kone *et al.*, 2006), *Synodontis membranaceus* (Owolabi, 2008), *Synodontis ocellifer* (Meye *et al.*, 2008), and *Synodontis nigrita* (Adeyemi *et al.*, 2009).

Scale-eating habits occur in many unrelated families of fish living in fresh waters (Marlier and Leleup, 1954; Fryer *et al.*, 1955; Roberts, 1970; Fryer and Iles, 1972) as well as marine environment (Whitfield and Blaber, 1978). In all cases, the scale-eating fish have developed specialized dentitions that enable them to pick scales from other fish. Fryer *et al.* (1955) observed the similarity in the mode of feeding between grazing cichlids with movable bands of teeth and *Genyochromis mento* that has relatively firmly fixed teeth. These authors suggest that scale-eating habit in *G. mento* might have evolved from grazing habit, with a change from movable to fixed teeth. This transition from herbivory to scale-eating habit may not be the case in *S. schall* in Lake Chamo, because the fish has a well-defined stomach and short intestine indicating carnivorous feeding habit. Moreover, the voracious nature of feeding habit of the species, sometimes to the extent of scavenging large quantities of fish offal discarded by the fishermen, suggests predatory mode of feeding rather than transition from herbivorous feeding habit. Large shoals are usually observed at shallow regions of the lake soon after the fishermen begin gutting the fish. *S. schall* must have been adapted in using their strong sense of smell in locating their food source. The presence of considerable quantities (about 21% by weight) of macrophytes in the stomachs of *S. schall* in Lake Chamo suggests some degree of omnivorous feeding habits. As the fish migrates between pelagic and littoral environments only about 10% of the population feeds on shoots, roots and seeds of macrophytes, but the contribution of food items of animal origin is by far more important to the nourishment of *S. schall* in Lake Chamo.

Scale-eating habit in *S. schall* in Lake Chamo may have evolved as a specialized form of carnivorous feeding habit. As this fish grows and moves to the pelagic waters, it is severely limited to handle large prey because of its small mouth. Since this fish has specialized teeth that are suited to pick scales from other fish, the most profitable ecological niche in pelagic environment is shifting to parasitic mode of feeding. Fryer and Iles (1972) suggest that scale-eating habit in the genus *Plecodus* in Lake Tanganika (East Africa) may be a modified predation. Marlier and Leleup (1954) reported that *Plecodus paradoxus* was exclusively scale-eater and refused to feed on any other source of food except fish scales in experimental condition. Whitfield and Blaber (1978) suggested that scale-eating habit of *Terapon jarbua* may have evolved as a modification of the carnivorous habit.

Juvenile *S. schall* (<20 cm FL) are restricted to the shallow littoral areas of Lake Chamo. At this stage the main diet of the fish consists of zooplankton, diatoms and insects. As the fish grow older they move to the deeper part of the lake and are commonly caught by the gill nets of the fishermen. The serrated and long dorsal and pectoral spiny fin rays normally expose them to the gill nets even at smaller size. The importance of zooplankton and insects declines sharply as the fish move to the pelagic water bodies. In this environment, piscivorous mode of life may not be profitable for *S. schall* because it is severely limited by its ventrally located small mouth to consume large fish and may have switched to scale-eating as a modification of piscivorous feeding habit.

The ventrally positioned mouth of *S. schall* is adapted for benthic feeding. However, terrestrial insects constituted significant proportion of total insects consumed by *S. schall* in Lake Chamo. The fact that *Synodontis* is able to swim in upside down position enables it to switch from benthic feeding to surface feeding depending on the availability and emergence of some food items (Bishai and Gideiri, 1965; Sanyanga, 1998). After conducting experimental feeding in tanks, Willoughby (1974) observed that *S. nigrita* swam upside down when feeding on the surface of the tank.

Importance of fish scales, macrophytes and fish fry increased with size. From the composition of the stomach contents of this fish it is evident that it makes diurnal migration between pelagic and littoral areas of Lake Chamo. Fry of *O. niloticus* are essentially restricted to the densely vegetated littoral areas where they can find refuge from predators. However, the importance of *O. niloticus* fry increases in the diets of *S. schall* as size increases. The

presence of fish fry is highly associated with plant materials including shoots, roots and seeds of macrophytes.

In conclusion, this study has clearly shown the type of diet and ontogenetic diet shifts of *S. schall* in Lake Chamo. The main components of the diet were zooplankton, fish scales and macrophytes. Fish fry, fish eggs, insects and diatoms were also ingested relatively frequently. Importance of diatoms, zooplankton and insects declined steadily with size of fish while importance of macrophytes, fish fry and fish scales increased with size of fish. The scientific information obtained is important for proper utilization and management of the stock because such a study is important to understand the trophic position of the species to maintain proper balance and dynamics that go with it.

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