Ethiop. J. Biol. Sci., 7(2): 123-137, 2008

ISSN: 1819-8678

FEEDING HABITS, ONTOGENETIC DIETARY SHIFT AND SOME ASPECTS OF REPRODUCTION OF THE TIGERFISH *HYDROCYNUS FORSKAHLII* (CUVIER, 1819) (PISCES: CHARACIDAE) IN LAKE CHAMO, ETHIOPIA

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ABSTRACT: The diet composition, ontogenetic dietary shifts and reproduction of the tigerfish *Hydrocynus forskahlii* (Cuvier, 1819) were studied from 386 fish samples (11.2 cm-69.6 cm total length, TL) collected from Lake Chamo from January to August 2005. From the total number of fish samples 231 (59.8%) that contained food in their stomachs were used in the analysis. Zooplankton occurred in 35.8% of the stomachs examined, accounted for 78.8% numerically and constituted 10.3% volumetrically. Insects occurred in 58.5% of the stomachs examined, constituted 20.8% of the total number of prey organisms and accounted for 38.7% of the total volume of the food items. Tilapia fry occurred in 43.4% of the stomachs examined, constituted 0.73% of the total number and 50.3% of the total volume of the prey. Macrophytes occurred in 18.9% of the stomachs and accounted for 0.74% of the total volume. *H. forskahlii* fed mainly on zooplankton when young and shifted to piscivorous feeding habit when it attained the size of about 25 cm TL. The sex ratio was significantly different from unity where 306 (79.3%) females and 80 (20.7%) males were caught during the sampling period. Relative fecundity of *H. forskahlii* ranged between 135 and 204, while mean fecundity ranged between 35,564 and 411,810. The relationships between fecundity (F) and TL ($F = 0.0184TL^{4.08}$, $r^2 = 0.61$) and F and total weight (TW) ($F = 36.89TW^{1.23}$, $r^2 = 0.70$) were curvilinear while the relationship between F and ovary weight (OW) ($F = 4082.9OW – 7949.5$, $r^2 = 0.88$) was linear.

Key words/phrases: Diet composition, *H. forskahlii*, Lake Chamo, Reproduction

INTRODUCTION

The tigerfish *Hydrocynus forskahlii* (Cuvier, 1819) is an open-water piscivore widely distributed in larger rivers and lakes of eastern, southern and western Africa (Jackson, 1961; Matthes, 1968; Gaigher, 1970; Holden, 1970; Winemiller and Kelso-Winemiller, 1994). In Ethiopia, its distribution is restricted to the Baro River basin in the west, the Omo River basin in the south west and the Ethiopian Rift Valley lakes: Abaya and Chamo in the south (Shibru Tedla, 1973).

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In southern Africa, *Hydrocynus* supports important commercial and recreational fisheries in the Zambezi, Okavango/Chobe Rivers and Lake Kariba (Winemiller and Kelso-Winemiller, 1994), but it is not a major part of commercial fisheries in Lake Chamo. With the recent over-fishing of *Lates niloticus* (L.), *Labeo horie* (Heckel) and *Oreochromis niloticus* (L.) in Lake Chamo, the attention of the fishermen has turned to other commercially viable fisheries such as *Bagrus docmak* (Forskål), *Clarias gariepinus* (Burchell) and *H. forskahlii* (Elias Dadebo, 2002).

Various authors have studied the feeding habits of *H. forskahlii* in some water bodies of Africa and emphasized its impact as a strong piscivore on other prey fish species (Jackson, 1961; Matthes, 1968; Holden, 1970; Gaigher, 1970; Lewis, 1974; Winemiller and Kelso-Winemiller, 1994). The available information indicates that *Hydrocynus* is amongst the most important freshwater predatory fishes in tropical Africa from Niger, Zaire, the Nile River basin, including Lakes Chad, Albert and Turkana (Gaigher, 1970; Kenmuir, 1972; Leveque *et al*., 1991). *H. forskahlii* feeds on zooplankton and other invertebrates at juvenile stage and shifts to piscivorous feeding habit when it attains a size of about 20 cm TL (Gaigher, 1970).

Information on the reproductive biology of *H. forskahlii* in African water bodies is meagre (Bell-Cross and Minshull, 1988; Kolding *et al*., 1992). So far no published information is available on the biology and ecology of this species in Lake Chamo. This paper deals with diet composition, ontogenetic dietary shifts and some aspects of reproductive biology such as sex ratio and fecundity of *H. forskahlii* in Lake Chamo, with the aim of providing the necessary scientific information for proper future utilization and management of the stock.

MATERIALS AND METHODS

Description of the study area

Lake Chamo ($5^o42'$ – $5^o58''$ N; $37^o27''$ – $38'$ E) is the most southern of the Ethiopian rift valley lakes and located at about 515 km to the south of the capital city, Addis Ababa (Fig. 1). It lies at an altitude of 1108 m and has an area of 551 km^2 and a maximum depth of 16 m (Amha Belay and Wood, 1982). Lake Chamo lies to the east of the Precambrian blocks of the Amaro Mountains within the less intensely faulted basin (Mohr, 1962). The main inlet of the lake is Kulfo River that flows in at the north end of the lake and the less important feeders are Sile and Sago Rivers, entering from the west. The surrounding region receives two rainy seasons per year, March-May

(Big rains) and September – October (small rains). The mean annual rainfall is about 1000 mm (Daniel Gamachu, 1977).

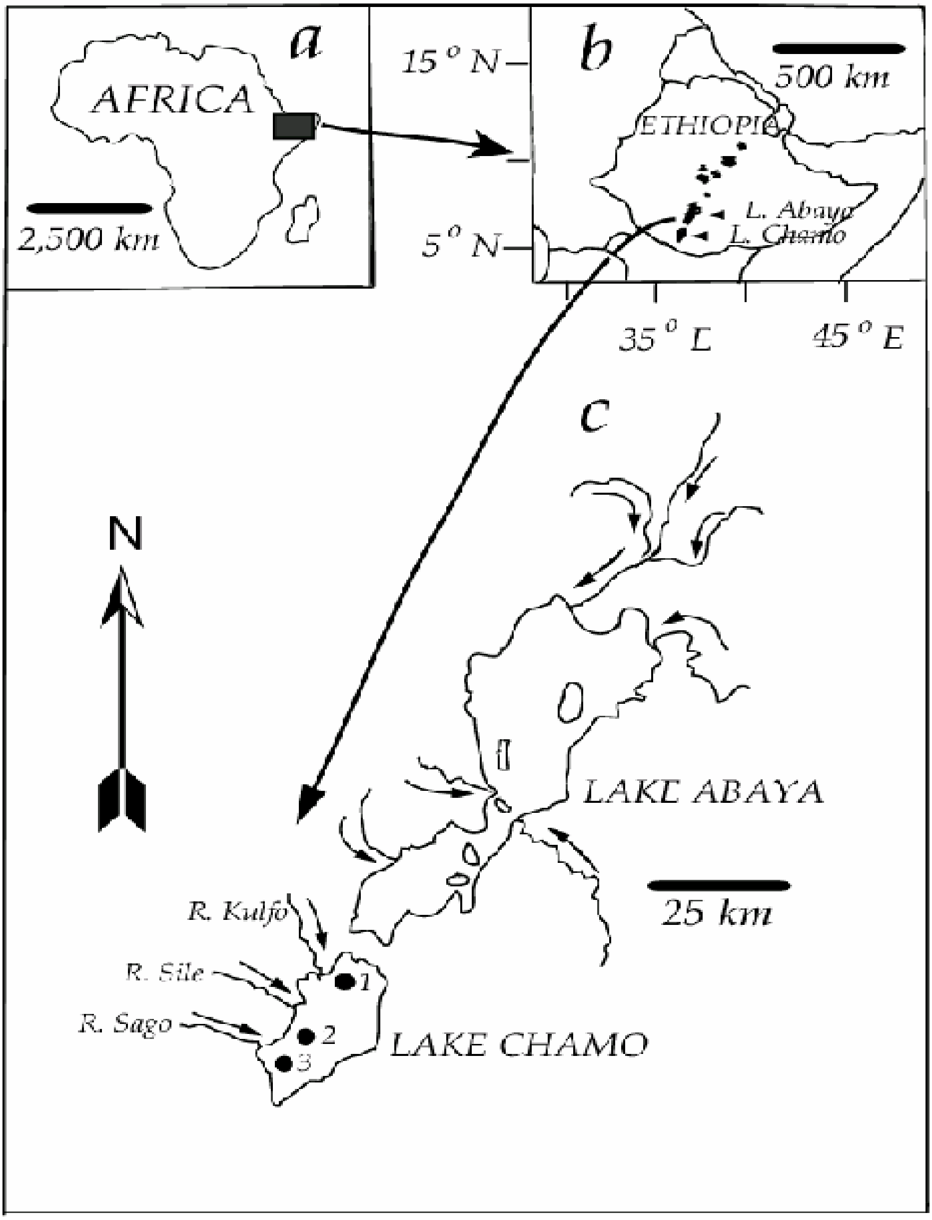

Fig. 1. Map of Africa with the relative position of the Horn of Africa highlighted (a), map of Ethiopia with the relative position of the Ethiopian rift valley lakes indicated (b) and map of Lakes Abaya and Chamo with the sampling stations in Lake Chamo indicated (c) (1-Deset, 2-Bedena, and 3-Bole).

The ichthyo-fauna of Lake Chamo, and also that of the neighbouring Lake Abaya, is Soudanian species (Beadle, 1981). The fish species are more diverse than that of the other rift valley lakes of the country probably as a result of the northward migration of the Soudanian species when the lake was in contact with the Nile system in the recent past (Beadle, 1981). There are more than 20 fish species in Lake Chamo and the inflowing rivers (Getachew Teferra, 1993). The commercially important species are *O. niloticus*, *L. horie*, *B. docmak* and *C. gariepinus*. Capture of *L. niloticus* has been banned for more than a decade now, as a result of sharp decline of the stock due to over-fishing.

Sampling

Fish samples were obtained from the shallow littoral area using a beach seine (20 m x 4 m) having a mesh size of 6 mm. In addition, gill nets of varying mesh sizes (20 mm, 30 mm, 40 mm, 80 mm, and 100 mm) were used in offshore areas of the lake to obtain larger fish. Gill nets were set at about 13.00 GMT (10.00 local time) and allowed to stay in the lake for a maximum of 2 hrs. This was done in order to minimize digestion of food items after capture. Three sampling sites were selected at different sites of the lake:

1. Deset-located at the northern side of the lake, close to an island called Kulfo-Ain. This site is assumed to be affected by the inlet river Kulfo,

2. Bedena-located at the pelagic area in the middle of the lake and

3. Bole-located at the southern part of the lake (Fig. 1.).

Total length (TL) was measured to the nearest millimeter and total weight (TW) was taken to the nearest 0.1 g. The length-weight relationship was determined using the least squares regression technique.

After dissecting, the stomach contents were preserved in 70% ethanol for further analysis in the laboratory. Identification of stomach contents was done visually for the large food items, but a dissecting microscope was used for smaller organisms.The relative importance of food items was determined using frequency of occurrence, percent composition by number and volumetric analysis. In frequency of occurrence the number of stomachs that contain a given type of food items was expressed as a percentage of the total number of non-empty stomachs examined (Windel and Bowen, 1978). In numerical method the number of items in each food category was expressed as a percentage of the total number of all food items in the stomachs examined (Windel and Bowen, 1978). In volumetric method of analysis, the volume of a given category of food items was expressed as a percentage of the total volume of food items (Windel and Bowen, 1978). Finally, the quantitative importance of each prey category in the diet was determined using the Index of Relative Importance (IRI) (Pinkas *et al*., 1971):

$$IRI = \%O\ (\%N + \%V) \qquad (1)$$

Where:

IRI = Index of relative importance,

%O = Percentage frequency of occurrence of the food items,

%N = Numerical percentage of the food items in the stomachs,

%V = Percentage by volume of the food items in the stomachs.

The sex and maturity stages of the gonads were determined by visual examination of the gonads and by use of a five-point maturity scale based on the method of Holden and Raitt (1974). According to this maturity scale, fish are categorized as: immature (I), recovering spent or developing virgin (II), ripening (III), ripe (IV) and spent (V).

Ripe ovaries were removed and weighed to the nearest 0.01 g and preserved in Gilson's fluid, as in Bagenal and Braum (1978). This fixative hardens the eggs and disintegrates the ovarian tissues. In order to facilitate the penetration of the preservative, the ovaries were split longitudinally and turned inside out (Bagenal and Braum, 1978).

Fecundity

After 72 hrs. of preservation, the eggs were shaken vigorously, washed in tap water, separated from ovarian tissues and weighed to the nearest 0.01 g. Fecundity was estimated by weighing all the eggs in the ovaries and counting three sub-samples of 1 g of eggs from different parts of the ovaries. Females in running condition were identified by slightly pressing their abdomens to see the release of eggs. In order to eliminate the problem that arises due to partially spawned out ovaries, fish found to be in running condition were excluded from the fecundity estimation.

The average number of eggs per gram of preserved wet weight was calculated and multiplied by the total weight of each ovary (Snyder, 1983) to calculate total fecundity, relative fecundity and mean fecundity. Total fecundity was estimated by determining the average number of eggs in three sub-samples of 1 g of eggs and multiplying the average number by the total weight of the ovaries. Relative fecundity was calculated by dividing the total number of eggs in a given size class by the total body weight of fish in the size class. Mean fecundity within a size class was calculated by dividing total fecundity within a size class by the number of fish.

The relationship between fecundity and some morphometric measurements was determined by relating total fecundity (F) data to TL, TW and OW by using the following formula (Elias Dadebo *et al*., 2003):

$$F = a \times TL^b \quad (2)$$

$$F = a \times TW^b \quad (3)$$

$$F = a + bOW \quad (4)$$

Where: a and b are parameters.

RESULTS AND DISCUSSION

Diet composition

H. forskahlii in Lake Chamo fed on a variety of food items including zooplankton, insects, macrophytes and fish fry. Within the size range of fish investigated, juvenile fish (10-25 cm TL) mainly fed on zooplankton while adults (>25 cm TL) fed on tilapia fry. Insects had comparable importance for all size classes of fish. The different food items identified from the stomach contents of *H. forskahlii* and their relative importance is given in Table 1. The difference in the prey type of the different size classes could be due to the habitat difference occupied by juveniles and adults. Juvenile *H. forskahlii* have the same need of protection like other prey organisms from predation of those of other piscivores like *L. niloticus* and *B. docmak* and therefore, are confined in shallow vegetated littoral area of the lake whereas the adults prefer the deeper pelagic areas.

Zooplankton contributed relatively higher frequency and number of the prey, occurring in 35.8% of the stomachs examined and accounting for 78,8% numerically. Volumetrically, zooplankton constituted 10.3% of the total volume of food items (Fig. 2). Zooplankton were the most important food organisms of juvenile *H. forskahlii* in Lake Chamo. Larger-sized zooplankton were strongly selected, suggesting that the mode of feeding was particulate feeding rather than filter feeding.

Insects occurred in 58.5% of the stomachs examined, constituted 20.5% of the total number of the prey organisms and accounted for 38.7% of the total volume of the food items (Fig. 2).

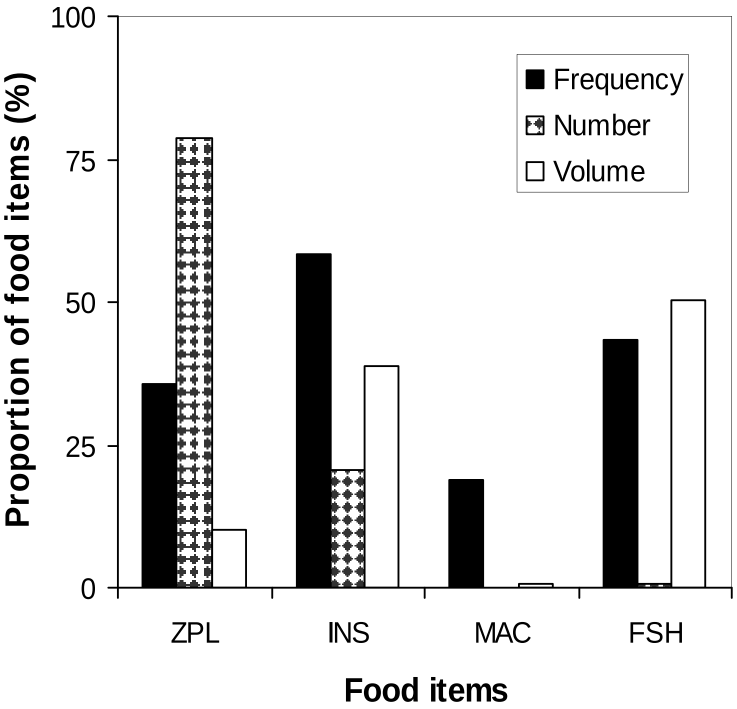

Fig. 2. The percentage contribution of prey organisms consumed by *H. forskahlii* in Lake Chamo using different methods of analysis (ZPL-Zooplankton, INS-Insects, MAC-Macrophytes, FSH-Fish).

Macrophytes occurred in 18.9% of the stomachs, and accounted for 0.74% of the total volume (Table 1, Fig. 2). Because of the small volume of these food items, their importance to the nourishment of the species was relatively unimportant. It is most probable that the ingestion of macrophytes could be incidental as the predator pursues its prey in shallow vegetated areas of the lake. Since tilapia fry and other invertebrates hide in the vegetated area, small quantities of macrophytes could be ingested as *H. forskahlii* hunts its prey in the littoral area.

O. niloticus fry occurred in 43.4% of the stomachs examined, constituted only 0.73% of the total number and 50.3% of the total volume of the prey (Table 1, Fig. 2). The importance of tilapia fry in the diet of *H. forskahlii* was evident because about 50% of the volume was accounted by this food item. The numerical contribution of tilapia fry was low because of the large volume of individual prey. Availability and ease of capture of the prey are probably the main reasons that *O. niloticus* was the main prey of *H. forskahlii*.

Table 1 Occurrence, numerical and volumetric index values and the corresponding IRI and %IRI values of the various food items in the diets of *H. forskahlii* from Lake Chamo.

Food items	%O	%N	%V	IRI	%IRI
Zooplankton					
Copepoda	22.50	22.00	4.60	598.5	8.7
Cladocera	37.70	56.70	5.40	2314.8	33.6
Insecta					
Chironomidae	25.10	17.30	28.70	1154.6	16.8
Micronecta	15.60	0.22	0.50	11.2	0.2
Notonecta	35.90	0.94	4.00	177.4	2.6
Anisoptera	3.00	0.00	2.60	7.8	0.1
Ephemeroptera	6.00	0.00	0.06	0.4	0.1
Other insects	11.70	2.10	3.20	62.0	0.9
Macrophytes	23.40	-	0.87	13.3	0.2
O. niloticus	50.20	0.74	50.10	2552.2	37.0

Ontogenetic dietary shifts

Volumetric contribution of different food items with size of fish is given in Fig. 3. In 15.0-24.9 cm size class, zooplankton were the most important prey organisms followed by insects. In 25.0-34.9 cm size class, the importance of zooplankton declined, while the importance of fish increased sharply. In 35.0-44.9 cm size class the contribution of zooplankton was negligible while *O. niloticus* fry contributed about 90% of the total volume of the food items (Fig. 3). Contribution of insects was more or less similar in all size classes (Fig. 3).

Lewis (1974) studied the diet of *H. forskahlii* (10.0-53.0 cm standard length (SL)) and *H. brevis* (19.5-64.5 cm SL) in Lake Kanji, Nigeria and found out that both species were exclusively piscivorous in their feeding habit. Gaigher (1970) studied the ecology of *H. vittatus* in Lake Chualo, South Africa and reported that fish <3.5 cm fed mainly on Entomostraca while in fish >5.5 cm, the most important single food item was fish. In the present study, the percentage contribution by volume of fish was only about 5% until the fish attained a size of 25.0 cm TL. The delay in shifting to piscivorous feeding in Lake Chamo could be due to the presence of other larger piscivorous fish species such as *L. niloticus* and *B. docmak* that normally predate on *H. forskahlii* (Hailu Anja and Seyoum Mengistou, 2001; Elias Dadebo *et al*., 2005).

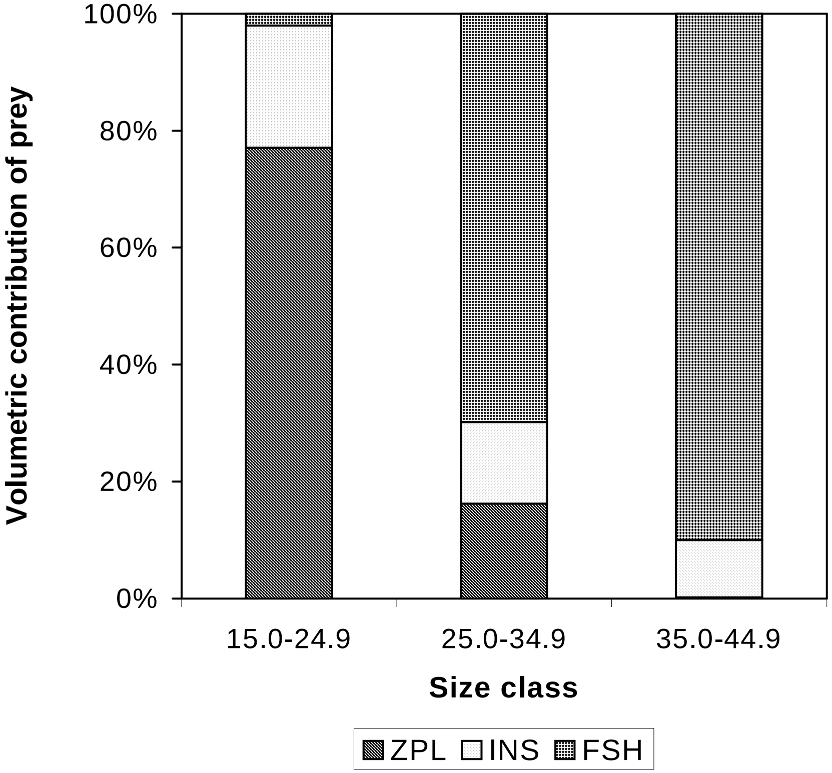

Fig. 3. The percentage volumetric contribution of prey organisms consumed by *H. forskahlii* at different size classes in Lake Chamo.

Based on the Index of Relative Importance (IRI) *O. niloticus* (2,552.2) was the most important food item followed by Cladocera (2,314.78), Chironomid larvae (1,154.6) and Copepoda (598.5) (Table 1). The relative importance of insects was comparatively low ranging from 0.36 (Ephemeroptera) to 177.4 (Notonecta) (Table 1)

Sex ratio

Of the 386 fish samples collected 306 (79.3%) were females while the remaining 80 (20.7%) were males. The females ranged in size from 14.6-69.6 cm total length (TL) and 23.0-2,500 g total weight (TW), while the males ranged in size from 11.2-37.6 cm TL and 8.0-300 g TW. There was no significant variation in the sex ratios of fish below 30 cm TL (Table 2). Females were more numerous than males in 30.0-39.9 cm size class (χ^2 = 37.12, p<0.001) (Table 2). No males were captured above 40.0 cm TL (Table 2). The overall sex ratio was significantly different from unity (χ^2 =

83.78, p<0.001) (Table 2).

Table 2 Sex ratios of *H. forskahlii* at different size classes from Lake Chamo.

Size class (cm)	Females	Males	Sex ratio (F:M)	χ^2
10.0-19.9	7	6	1: 0.86	0.08
20.0-29.9	25	21	1: 0.84	0.35
30.0-39.9	101	31	1: 0.31	37.12***
40.0-49.9	56	0	-	-
50.0-59.9	13	0	-	-
60.0-69.9	5	0	-	-
Total	207	58	1: 0.28	83.78***

***- Very highly significant

A preponderance of females over males was evident in all size classes. Variations in sex ratios of some piscivorous fish species have been attributed to segregation of the sexes at different habitats and also due to a tendency of one sex preceding the other in moving to breeding grounds (Morgan and Gerlach, 1950; Lowe McConnell, 1958; Hopson, 1972; 1982). Mansueti (1961) reported that the white perch *Morone americanus* (Gmel.) preceded females to the spawning grounds in the Patruent River, Maryland. As a result, during the early migration to the breeding grounds males out-numbered females, but simultaneous sampling in the estuary downstream revealed that females were more abundant than the males. Elias Dadebo (2002) reported the segregation of the sexes of *H. forskahlii* in Lake Chamo at different seasons of the year. According to Elias Dadebo (2002) more females were caught from March to June (male: female; 1: 45) during the major rainy season whereas males predominantly make up the catch in August with a sex ratio of 1: 10 (female: male). In the present study, females were more numerous than males during the whole sampling period and preponderance of males over females was not encountered during the dry months of the year. Since sex segregation is usually habitat specific, such lack of male preponderance during the dry months could be due to inability to sample areas where the males congregate.

Length-weight relationship

Length-weight relationship between TL and TW of *H. forskahlii* was curvilinear and statistically significant (Fig. 4). The relationships between TL and TW of males, females and both females and males combined were as follows:

Males: $TW = 0.0052TL^{3.0444}$, $r^2 = 0.989$, n = 80 (5)

Females: $TW = 0.0042TL^{3.1124}$, $r^2 = 0.954$, n = 306 (6)

Males and females combined: $TW = 0053TL^{3.0443}$, $r^2 = 0.970$, n = 386 (7)

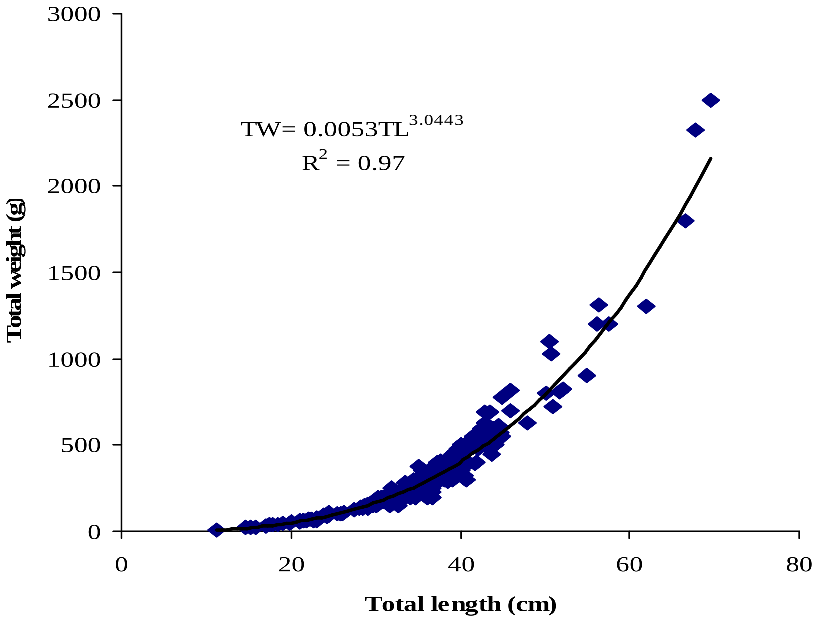

Fig. 4. Length weight relationship of *H. forskahlii* in Lake Chamo.

Fecundity

Fecundity varied greatly among fish of the same length. The majority of large fish were in running condition; therefore they were not included in the fecundity estimation. The total number of eggs per female ranged from 17,643 to 595,046 with the mean of 80,683 eggs. Relative fecundity of *H. forskahlii* ranged between 135 and 204, while mean fecundity of the fish ranged between 35,564 and 411,810. Both relative fecundity and mean fecundity of *H. forskahlii* in Lake Chamo increased with size of fish (Table 3).

Table 3 Relative fecundity and mean fecundity of *H. forskahlii* from Lake Chamo.

Size class (cm)	Number of fish	Relative fecundity	Mean fecundity
30.0-34.9	5	135	35,564
35.0-39.9	25	155	4,694
40.0-44.9	17	189	96,094
45.0-49.9	7	192	110,415
50.0-54.9	3	197	125,862
>55.0	2	204	411,810

The relationship between TL and F ($F = 0.0184TL^{4.08}$, $r^2 = 0.61$, n = 59) and between TW and F ($F = 36.89TW^{1.23}$, $r^2 = 0.70$, n = 59) were curvilinear (Fig. 5) while the relationship between F and OW ($F = 4082.9OW-7949.5$, $r^2 = 0.88$, n = 59) was linear (Fig. 5).

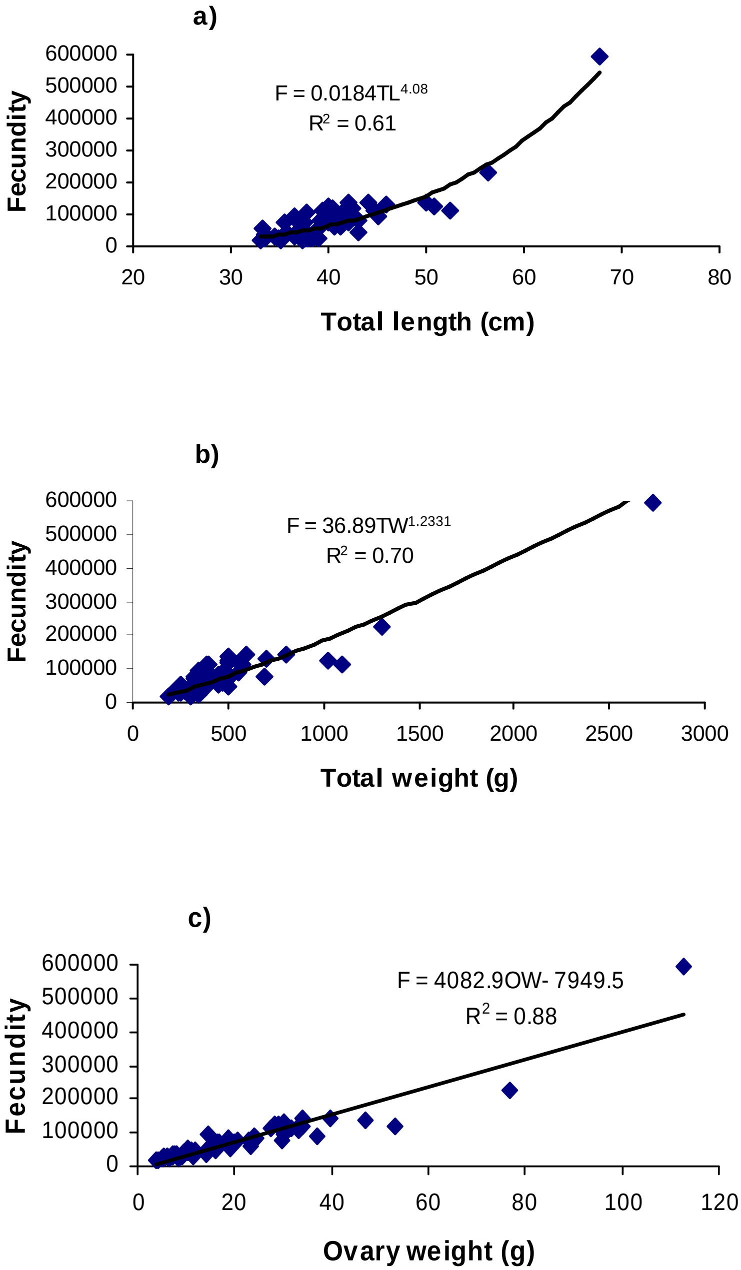

Fig. 5. Relationship between (a) fecundity and total length, (b) fecundity and total weight, and (c) fecundity and ovary weight of *H. forskahlii* in Lake Chamo.

Fecundity of *H. forskahlii* in Lake Chamo increased in proportion to 4.08 power of TL and to 1.23 power of TW (Figs. 5a, b). Wootton (1979) estimated fecundity values of 62 different temperate fish species and reported *b* values between 1 and 5, most values falling between 3.25 and 3.75. Hailis and Abdullah (1982) compared *b* values of 12 tropical species and the values fall between 2.915 and 3.958. Fecundity varies greatly between fish populations (Thorpe, 1977a) and also varies within populations (Tsai and Gibson, 1975; Brazo *et al*., 1975). Thorpe (1977b) considered the variation in a single habitat and suggested that differences in food supply, spawning conditions and degree of exposure to the wind may be responsible.

In conclusion, *H. forskahlii* in Lake Chamo feeds on a variety of food items including zooplankton, insects, macrophytes and fish fry. Zooplankton was the most important food item of juvenile (<25 cm TL) *H. forskahlii* whereas fish fry (*O. niloticus*) were the most important food items of adult fish. Both juveniles and adults consumed insects in fairly similar proportions. Macrophytes were of low importance because their volume was relatively low. A preponderance of females over males was evident because more than 79% of all fish captured were females. *H. forskahlii* is a highly fecund fish where the total number of eggs in the ovaries ranged from 17,643 to 595,046 with a mean of 80,683 eggs. Relative fecundity as well as mean fecundity increased with size of fish. The relationships between F and TL and F and TW were curvilinear while the relationship between F and OW was linear.

ACKNOWLEDGEMENTS

We thank Mengistu Balcha for his assistance during the field work. We are grateful to Applied Biology Department (Hawassa University) for providing laboratory facilities and logistic support of the field trips.

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