Effect of Season on Catch rate, Diet and Aspects of Reproduction of Clarias gariepinus (Teleostei: Clariidae) in a Tropical Waterfalls

Gabriel U. Ikpi[1], Adetola Jenyo-Oni[2], Benedict O. Offem[3,*]

[1]Department of Fisheries and Aquatic Science, Faculty of Agriculture and Forestry, Cross River University Of Technology, Obubra Campus, Cross River State, Nigeria
[2]Department of Wildlife and Fisheries Management, Faculty of Agriculture and Forestry, University of Ibadan, Nigeria
[3]Department of Fisheries and Aquatic Science, Faculty of Agriculture and Forestry, Cross River University Of Technology, Obubra Campus, Cross River State, Nigeria

Abstract The African catfish *Clarias gariepinus* (Burchell 1822) are highly valued food-fish and are among the dominant fishes of commercial catches in major rivers in Africa. The aim of the present study was to provide data on reproductive biology, diet habits, length–weight relationship and condition factor that can be useful for conservation and propagation of this species. The study was carried out over 24 months in the three reaches of the 200 km- long of Agbokum waterfalls, Nigeria. The influence of season on catch rate, reproduction and diet was determined from catch samples. There was a significant difference in the catch rate between the dry and wet seasons. Peak catch occurred during the early and late rains. The peak breeding period was June - July. The fish were omnivorous, with trophic flexibility being related to food availability. The condition of the fish was better downstream of the waterfalls than the other two reaches, but declined during dry season and improved during early and late rains. Therefore downstream reaches during wet season are significant in the fisheries studies of waterfalls

Keywords Waterfalls, Catch Rate, Fecundity, Diet Habit, Condition Factor, Season

1. Introduction

Clarias gariepinus belong to the family Clariidae and occur in most freshwater bodies of South East Asia and Africa where they constitute a significant component of the catches. The highest genetic diversity is found on the African continent where some 14 genera have been reported[1] against two in Southeast Asia. They have high market value in Nigeria and the world at large, and a vital source of vitamins and protein which are highly digestible[2]. They are very strong and easily adapted to their environment; they are inexpensive in term of the cost of production when cultured. They live in freshwater lakes, rivers, swamps, as well as human-made water bodies, such as ponds or even urban sewer systems[3]. *Clarias gariepinus* commonly refer to as African Catfish is a large, eel-like usually of dark gray or black coloration on the back, fading to a white belly. It has a slender body, a flat bony head and abroad terminal mouth with four pairs of barbell[4].

In both continents Clarias gariepinus are of great economic importance as food fish and vital in the sustainability of aquaculture due to their attributes[5] which include; abil ity to withstand handling stress, disease resistance, high growth rate, yield potential, fecundity and palatability[6]. There is acute reduction of these species in inland waters in Nigeria because of the over-exploitative nature of indigenous fishers that destroys the habitat and fisheries resources[7]. Knowledge on their biology is important for rational utilization of stock. An effort by the Nigerian government to conserve and propagate these species through fisheries regulation and fish breeding is being hindered because of the little information available on the ecology of these species in Nigerian waters. Most of the research works are limited to the reproductive biology of *C. gariepinus*[8, 3, 10‒13]. No work had been undertaken on the ecological studies of *C. gariepinus* in Waterfalls. This paper therefore provides information on the ecological influence of season on the distribution catch rate, diet and reproduction of *C. gariepinus* in waterfalls of Southeastern Nigeria. These data will form the bases for management strategy of this species in waterfalls in Africa.

2. Materials and Methods

Study area. The study area is Agbokim Waterfalls in

Cross River State, Nigeria (Figure 1).

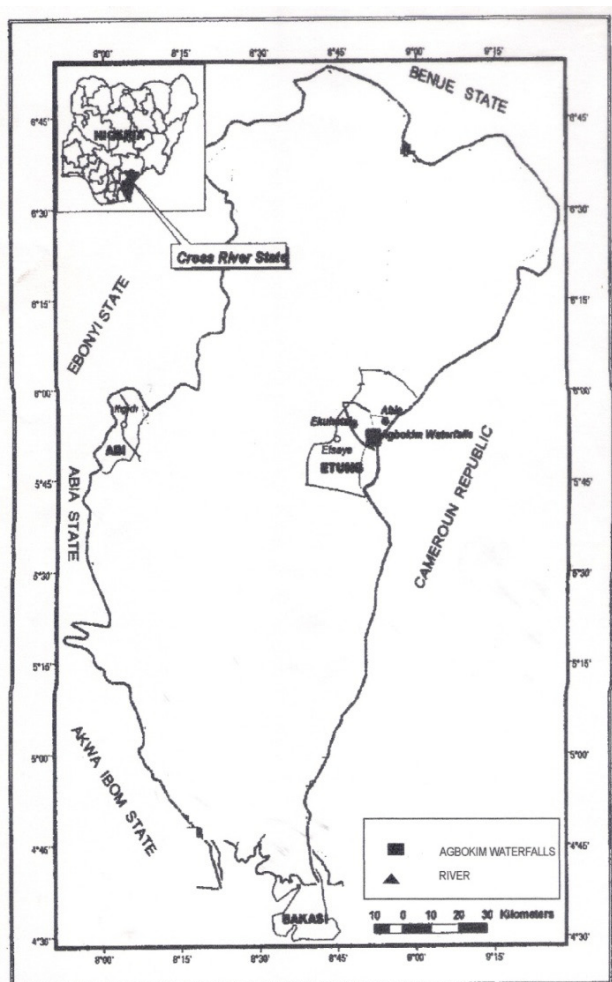**Figure 1.** Map of Cross River State showing Agbokim Waterfalls

Agbokim Waterfalls is located in latitude $5^0 59'$ North and longitude $8^0 45'$ East. It is bounded in the West by the Cross River and in the North by the Cameroon high forests. The climate of Agbokim Waterfalls is the tropical hinter-land type, with wet (May-November) and dry (December-April) seasons. Mean annual temperature ranged between $20^0 C$ and $32^0 C$ and annual total average rainfall, from 1450mm to 3015mm. The vegetation is the rainforest type with Soil consisting of deep laterite and dark fertile, clayey and loamy soils. Agbokim Waterfalls is drained by two small rivers, Ekue and Bakue, which are tributaries of the Cross River system. Of ecological importance are numerous small pools and swamps which are found along the length of the water-falls. The high annual discharge and rainfall of the Agbokim Waterfalls provide excellent buffers against natural eco-logical stresses such as drought[14] which can lead to the loss of important fish taxa. The total length of the waterfalls is 6817.73m. For the purpose of this study the waterfalls is divided into upstream, midstream (region of water fall) and downstream reaches. Upstream is close to cocoa farms with high forest cover along its shoreline and moderately fast water currents during the dry season and very fast water current during the wet season. Midstream has heavy water turbulence during the wet season and moderate water tur-bulence during the dry season with shoreline sparsely shaded with vegetation while downstream water current is low with an extensive wide area. The length upstream is 2003.13m, midstream 807.42m and downstream 4007.18m. Mean width upstream, midstream and downstream are 26.34 ± 2.2m, 32.84m and 40.52 ± 10.9m, respectively. Upstream mean height is $31.87 + 3.4$m while the depths upstream and down-stream are dependent on variation of the volume of water from rainfall and water discharge.

Three sampling sites were selected along the length of the water falls, with one site occurring in each of the reaches. Fish samples were collected once every month from 10 randomly selected fishers from each reach by day (0830-1200hours) and night (2400-0600 hours). The fishing gears comprised mainly seine net (10 - 34mm stretched mesh size) and gill net (22-76mm stretched mesh size). Distribu-tion pattern of the fish in the study area was investigated in the field. Fish samples were preserved in 10% formalin prior to laboratory examination. In the laboratory, data obtained from each fish included; length, weight, sex, fecundity and food records. Standard length (SL) and total length (TL) were measured to the nearest 0.1cm and weighed (wt) to the nearest 0.1g. Samples were identified using FAO Species Identification Sheet[15] and other authors[16, 17, 18] and sexed by visual observation of the gonads.

Specimens for diet studies, were dissected and their guts removed immediately after capture and stored in formalde-hyde solution (4%) until the contents were analyzed[19]. Gut analysis was later carried out, food items identified to the lowest possible taxon and analysed quantitatively for per-centage composition by number (N) and frequency of oc-currence (FO)[20, 21]. Percent composition by number is the percentage of the number of food items examined accounted for by selected taxa. Frequency of occurrence describes the percentage of fish with non-empty gut that contained at least one of a selected food item. In calculation unidentified food items were not used.

Analysis of fecundity was limited to the peak spawning period (May-July) and only ripe female fish (494) were used for the estimation. Ovaries were removed from body cavity of each fish, weighed and preserved in Gilson fluid[22]. This method of preservation hardened the eggs, break down ovarian tissues and liberate the eggs. Ovaries of each fish were preserved for seven days before the eggs were counted. The preserved ovaries were washed to remove the preserva-tive. Eggs were separated from tissue and placed on filter paper to remove excess water before being weighed using metler P 1210 chemical balance. Only the largest eggs (2.0-3.0mm) in each sample were used for fecundity esti-mation. Eggs in a l-gram sub-sample were counted. Counting was done for five similar sub samples. The mean number of eggs in the five sub samples gave the number of eggs per gram of weight. Fecundity was calculated by multiplying the total weight of eggs by the number of eggs per gram weight. Relative fecundity (RF) = No. of eggs per unit length (cm)

Data treatment

Fecundity - length and fecundity-weight relationships were determined using the expression by King (1991).

$$F = ax^b$$

F = absolute fecundity, x = independent variables (body weight, total length). a = scaling constant representing the intercept, b = allometric coefficient both of which were evaluated by least squares regression analysis using log transformed data; log F = log a + b log xi. Length at first maturity was worked out by plotting the percentage of mature fish against their lengths. Lengths at which 50% of the females were mature, was considered length at first maturity. It was calculated by an equation generated from the graph. Gonad cycle was determined from changes in gonad weight, as shown by Gonado-somatic Index (GDI) calculated by expressing the gonad weight as percentage of body weight[23].

Fulton's condition factor (CF) was determined[24],

$$K = \frac{W\ 100}{L^3}$$

K= condition factor, W = total weight (g) and L =total length (cm).

Diet breath estimates the diet spectrum and was calculated using the diversity index of Shannon-Wiener (H); H = -∑ pi × ln pi Where, pi is the proportion by the number of food type i, Food richness; expressed using Margalef's index: d= (S-1)/logN where d= Margalef's index, S is the number of species and N is the number of individuals[25] and Gut Repletion Index (GRI) which is the percentage of non-empty stomach was estimated[26].

Statistical analysis

Data collected were collated and analyzed using descriptive statistics (mean, standard deviation and percentage). Statistical comparison of data between and within reaches were carried out using analysis of variance (ANOVA)[27] and line graphs using excel statistical package (2007). Linear regression was employed to determine the type of relationship between any given pairs of variables. Correlation analysis was used to ascertain the significance of these relationships. The variability in data were evaluated using the coefficient of variation (CV) and the F – ratio test[28].

3. Results

Monthly variation in catches revealed that peak catch was biphasic occurring in the early (May-July) and late wet months (November-January) in all the reaches (Figure 2A-B). Catches of the juvenile fish was significantly higher (p<0.001) in the early wet months (May-July).

The maturity curve showed that 50% of the males matured at 16.5cm TL and females at length 14.6cm (Figure 3). GSI varied from 8.9 to 20.6 in female fish and from 4.2 to 12.5 in male fish and was higher in the wet season than dry (p<0.05). Monthly changes in the GSI of *C. gariepinus* females and males in consecutive months revealed that both values were very low during September to February and highest in May (Figure 4).
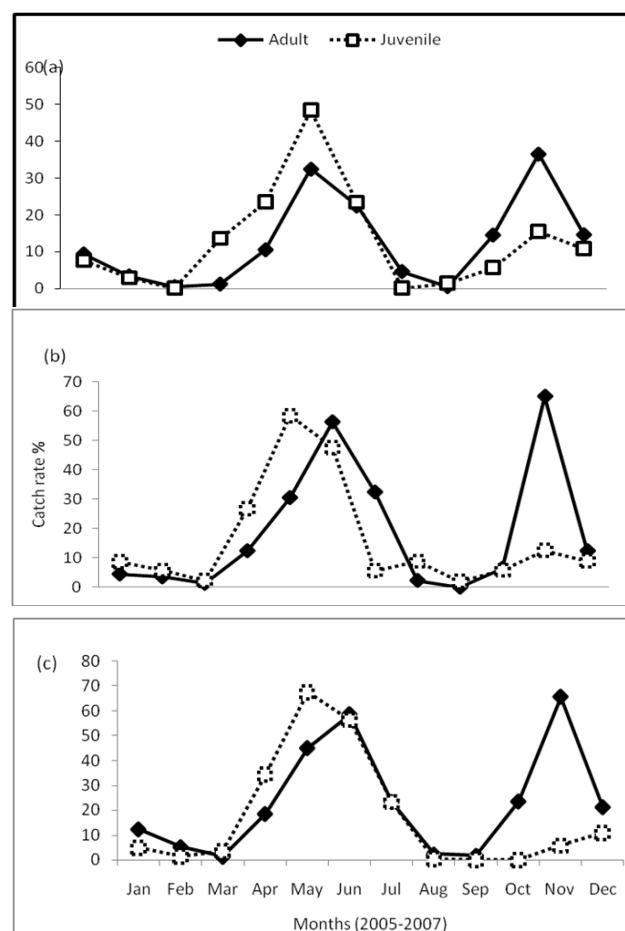

Figure 2. Percentage monthly catch rates of adult and juvenile of gariepinus in the Agbokum waterfalls: (a) upstream, (b) midstream and (c) downstream reaches

Absolute fecundity varied from 12576 and 103,984 while mean fecundity from 12151±22 52 eggs for fish with SL = 23.8cm and weight 167.6g in upstream reaches to 56203±12077 for fish SL = 65.9cm and weight = 878.8g in downstream reaches. Relative fecundity ranged from 339 to 408eggs g^{-1}. Figures 5A and B showed positive and linear relationship between total length, body weight and fecundity indicating that fecundity increase as body size increased. r^2 value was 0.657 for total length vs fecundity and 0.876 for body weight vs fecundity.
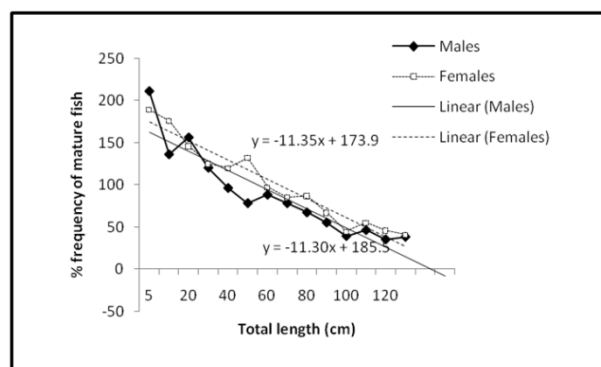

Figure 3. percentage occurrence of mature males and females *C. gariepinus* at different lengths
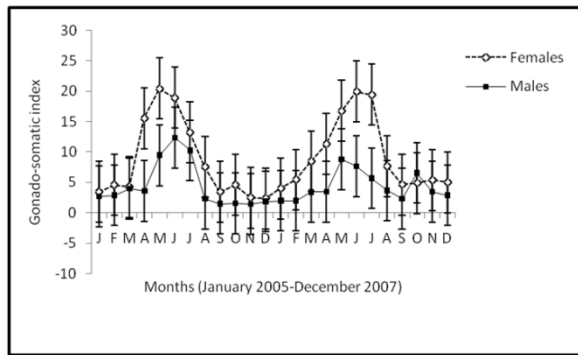
Figure 4. Dynamics in the gonadosomatic index (GSI) of the male and female *C. gariepinus* in Agbokum waterfalls
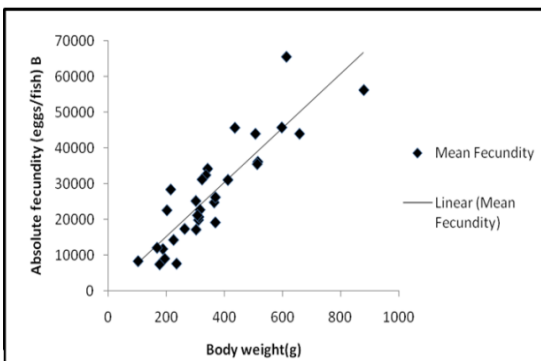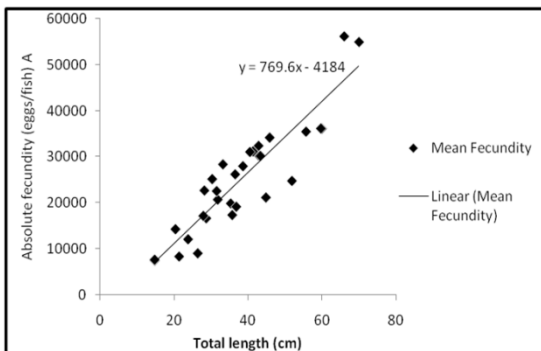

Figure 5. (a) Fecundity-length relationship and (b) fecundity-weight relationship
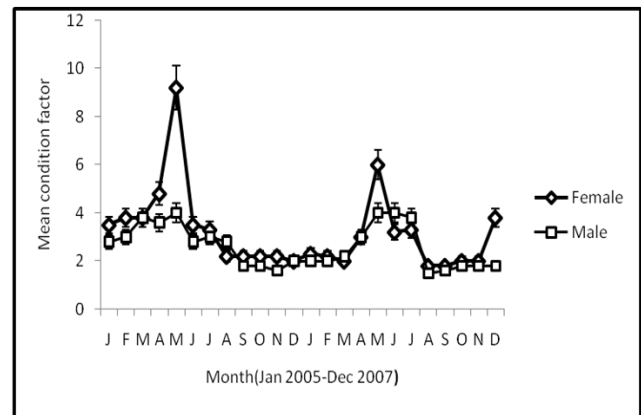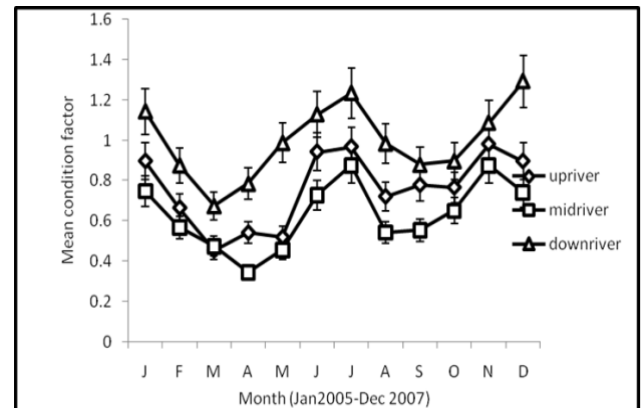

Figure 6. Monthly mean variation of condition factor of male and female *C. gariepinus* combined from Agbokim waterfalls by (a) reach and (b) sex

Mean condition factor ranged from 0.538±0.176 minimum in the upstream reaches to 0.880±0.204 maximum at the downstream reaches with significant (P< 0.05) difference between reaches. Also, there was significant monthly variation in the condition factor with both sexes recording highest condition factor between June and July and between November and January. Least values were obtained from February to April and August to October (Figure 6).

Table 1. Seasonal changes of frequency of occurrence and composition by number of food items in the stomach of the clarid catfish *C. gariepinus* in Cross River inland wetlands

N = 150	Wet season		Dry season	
Food items	% freq of Occurrence	% composition by number	% freq of occurrence	% composition by number
Annelid worm	1.2	2.9	4.5	1.9
Nematode worm Insects	-	-	7.1	1.0
Adult	7.6	4.2	9.2	15.1
Stages	9.5	12.2	10.2	13.5
Crustacean:				
Bivalves	15.2	2.9	6.4	4.3
Gastropods:	7.2	8.4	18.0	22.3
Decapods:	18.6	7.8	20.8	24.4
Fish:				
Whole adult fish	8.4	14.6	-	-
Fish juveniles	29.5	21.8	4.8	6.3
Fish remains	27.1	15.6	5.2	2.4
Rotifers	4.8	3.5	-	-
Plant materials	1.3	4.6	14.8	10.5
Food richness	11.2		8.2	
Diet breath (H)	4.7		0.5	
Gut repletion index	85%		85%	

H = Shanon-Wiener diversity index

Table 2. Diel variations in the food habits of *C. gariepinus* in the Cross River inland wetlands

No 150								
Method								
Frequency of occurrence				Numerical				
	Day	Night	X^2	P	Day	Night	X^2	P
Annelid worms	4	45	12.7	>0.001	23	59	12.9	>0.001
Nematode worm	5	23	10.3	>0.001	10	56	18.3	>0.001
Insects:								
Adult	-	189	-	-	-	387	-	-
Stages	121	311	295.8	<0.001	524	384	45.7	<0.001
Crustacean:								
Bivalves	43	98	77	<0.001	123	178	139.8	<0.001
Gastropods	66	522	206.6	<0.001	209	432	173.6	<0.001
Decapods	76	212	167	<0.001	87	198	101	<0.001
Fish								
Whole adult fish	-	234	-	-	-	411	-	-
Fish juveniles	-	444	-	-	-	501	-	-
Rotifers	-	77	-	-	-	132	-	-
Plant materials	309	98	111.3	<0.001	569	189	227.4	<0.001
Food richness	7	11			7	11		
Diet breath (H)	0.78	1.89			1.23	2.78		
	67%	92%			67%	92%		

The most frequent food item found in the African catfish in all the reaches were fish prey and fish remains constituting 65 percent of the diet in the wet season and <10 percent in the dry season (Table 1). Food objects, habitually, dominating the dry season, included crustaceans, insects, and plant materials, constituting 79% of the diet. Indices of the diet composition showed that Gut Repletion Index (GRI) was 85% in both wet and dry season and 67% and 92% in the day and night, respectively. The least prey diversity was found in dry season diet (H =4.7 and 0.5 for wet and dry seasons respectively). Diel pattern in the consumption of food items by *C. gariepinus* showed eleven food types ingested during the night while seven types were taken during the day (Table 2). The occurrence of all items except plant materials was significantly higher (P < 0.05) in the night catches than the day.

4. Discussion

The seasonal variation in the catch rate of *Clarias gariepinus* as indicated in the analysis of variance support the notion that various fish communities show non-random patterns in composition over time[29, 30]. Seasonal variation in catch rate may be as result of the period of courtship, during which and resting take place and the species withdraws to suitable and safe areas for spawning[31]. Peak of GSI for this species in April-May was confirmed by the largest frequency of the matured phases during this period; characterizing a single annual spawning, and synchronic ovarian development. By June/July, spawning was over, as indicated by the decrease in GSI and the presence of freshly spent ovaries. It has been reported[32] that the final trigger of spawning in *Clarias* species is caused by a rise in water level due to rainfall; which commenced in the study area between

April and June[33, 34] all found out that in some localities catfishes present a single annual spawning period corresponding to the late dry season or early wet season, associated with high water temperature. Our findings indicate that, for captive breeding programs gravid fishes are available in the wild during April-August. During October to January most ovaries were spent, indicating that the spawning period was over. Therefore, from the point of view of fisheries management the best fishing period for the species in the Agbokom waterfalls is October- January because gravid fish are almost absent during the period. Although the juveniles are abundant during the period, with the use of appropriate fishing methods and management practices such as regulated mesh size (>62.8mm stretched mesh), juvenile overfishing could be avoided, and only the table sizes will be harvested. A closed season, or less intense fishing, during April to September, when gravid *C. gariepinus* are abundant, would help to conserve the natural stocks, by allowing the fish to breed at least once in their lifetime.

The relative fecundity range of 453-678 eggs cm^{-1} recorded in this study was comparatively high compared to observations from other clariid catfishes. 308-403 eggs cm^{-1} from *C. gariepinus* had been recorded in Hardap dam, Namibia[8] and 203-278 eggs cm^{-1} in Cross River[35] while 443-498 eggs cm^{-1} were reported in Opa reservoir, Nigeria[9]. This shows that *C. gariepinus* in waterfalls may be more fecund than those in other fresh water bodies. Peak season in fecundity of these species which coincides with onset of rains and the rising flood have also been observed in the River Niger[36, 37, 38]. All concluded that most tropical fishes breed on the rising flood thus allowing the juveniles to take full advantage of the flooded banks for feeding, while being protected from predation. There are indications that the intensity of flooding influences the reproductive success as stronger year classes have been noted from those years

when particularly intense floods occur in the Kafue River and the Central Delta of the Niger, Senegal and Lake Chad (Stauch, Kainji Research Institute, Nig.(pers. comm.)

Our data show that condition factor is highly correlated with GSI. However, with higher GSI the weight for length is bound to increase, irrespective of whether or not the food organisms are in good or bad condition. The higher condition factor obtained between June and July, and low values between August and October, marched findings reported[34] and the results attributed to spawning activities, which may have resulted from the

accumulation of fats and ripe gonads carried by the mature adult females. The observation that 62% of the samples examined had condition factor above mean showed that the majority of fish in the population are in excellent condition[39].

The diet composition showed *C. gariepinus* to be an omnivorous predatory fish. The diet spectrum in which fish prey and crustaceans were the most abundant, could be closely marched with that obtained in *Clarias gariepinus* from Ubangui River, Central African Republic[40], in Lake Sibaya, South Africa[41], in Lake Kinneret, Israel[42] and in Southern Florida[43]. There is considerable seasonal variation in the feeding activity correlated with flood regime. During floods the release of nutrients, rapid growth of vegetation and the increased availability of other sources such as seeds, young shoots, leaves and molluscs form the basis for a particularly intense feeding activity[44]. The diet generally reflects the seasonal distribution of macro-invertebrates and fish prey in the environment[45, 46]. Presence of plant materials in the diet of this species had been reported[47, 48] and it was suggested that the frequent occurrence, especially during dry season, could be a survival strategy in times of scarcity of prey. The gut repletion index of 85 percent indicates that the fish is a regular feeder. High values of other indices such as Food Richness and Diet breadth showed that the species exhibits trophic flexibility, an ecological advantage that enabled the fish to switch from one food category to another in response to fluctuation in their abundance[49].

The diel pattern of feeding, where *C. gariepinus* completely ignored fish prey during the day and fed mainly on invertebrates and plants, was also observed[41]. He attributed this behavior to its inability to catch prey fish in daylight due to its slow, methodical, predatory tactics. The generally higher diet indices recorded from night catches in this study had also been reported[43] and suggested that the species is more active at night.

5. Conclusions

The species exhibits trophic flexibility, an ecological advantage that enabled the fish to switch from one food category to another in response to fluctuation in their abundance. Majority of fish in the population are therefore in excellent condition. A closed season, or less intense fishing, during April to September, when gravid *C. gariepinus* are abundant, would help to conserve the natural stocks, by allowing the fish to breed at least once in their lifetime.

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