

Feeding Ecology and Reproductive Biology of Some Economically Important Fish Species in the Tono Reservoir, Ghana

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Abstract. The study of feeding ecology and reproductive biology ensures that the right management measures are applied for best output of fish stocks. Selection of good fish species for culture is also made possible through feeding and reproductive studies. Ghana over-relies on the culture of Nile tilapia and African catfish because there is no reliable scientific information on potential fish species that can be included for fish farming. The current study sought to investigate food habits and reproductive characteristics of economically important fish species in the Tono Reservoir of Northern Ghana. Monthly sampling was carried out from January, 2015 to December, 2016 (24 months). Specimens were obtained using cast net and gillnets of varying mesh sizes. Specimens were immediately transported to the laboratory in a chilled iced chest of temperature 4 °C for morphometric measurements and microscopic analysis of gut content and gonads. Thirty-three (33) individual food items were identified from all the fish species. Phytoplankton was the most important diet (Index of Relative Importance, IRI = 1923) whereas zooplankton was the least important diet (IRI = 35) out of the five major categories of food items identified from all the fish species. The major peaks of gonadosomatic index (GSI) of females were noted in February – March and June – July. Over 80 % variation of fecundity was explained by the predictors (standard length, fish weight and gonad weight) for *Clarias gariepinus* and *Auchenoglanis occidentalis*. All the fish species were classified as omnivores and they spawned more than once in a year making all of them good candidates for aquaculture. Management measures should focus on regulating agricultural activities close to the reservoir and fishing activities in the reservoir for sustainable fish production and exploitation.

Introduction

Scientific knowledge and understanding of key population characteristics such as feeding and reproduction of fish are very necessary in the assessment and formulation of prudent management policies for fish stocks [1, 2]. Similarly, complete information of feeding and reproduction of fish populations is vital for increased fish productions in capture fisheries and in aquaculture [3]. The accurate estimation of these parameters is crucial in any dependable fish stock assessment. In recent times where most capture fisheries are suffering from over-exploitation [4] trophic levels and mandatory release of egg-bearing females of some species among others are imperative in outlining different sustainable management measures of any fishery [5]. The life history of fishes is well understood by studying fecundity [6] and food habits [7]. Food habits are especially important because fish growth depends on the quantity and quality of food that is eaten. Food habits are described by identifying the species of food in the contents of the alimentary canal and their weight. The availability of data based on feeding ecology and reproductive biology could lead to a better understanding of differences in food habits and reproductive output of fish which would enhance the ability to estimate recruitment [8].

In Ghana, little is known about food ecology and reproductive biology of many freshwater fish species except few studies carried out by [9-12]. Though these previous studies have established basic information about selected freshwater fish species, they have not been able to explain the index of relative importance (IRI) of food items consumed by fish and have not indicated a regression model between fecundity and morphometric measurements like length and weight for clearer understanding

of trophic levels and optimal foraging behavior [13] as well as key factors that affect fecundity of fish species. Results of the current study will give direction for fisheries management policies as well as render informed decision on the selection of new indigenous fish species for aquaculture. The main objective of this study was to investigate food habits and reproductive characteristics of economically important fish species in the Tono Reservoir of Northern Ghana.

To better understand factors influencing the food habits of the fish species, the following hypotheses were made. It was predicted that food items consumed by fish species will not vary with seasons. Furthermore, it was predicted that economically important fish species consumed different food items. Variables affecting fecundity of economically important fish species were also explored. It was predicted that the sex ratios of economically important fish species was the same. Additionally, factors such as standard length, fish weight and gonad weight of female specimens were predicted to influence fecundity.

Materials and Methods

Study area

The study was conducted in the Tono Reservoir situated on latitude $10^{\circ} 52' N$ and longitude $1^{\circ} 08' W$ (Figure 1). The construction of the reservoir began in 1975 and completed by 1985 mainly for irrigation and cattle watering purposes. The irrigation reservoir is the largest in Ghana [14] with storage capacity of $93\,000\,000\text{ m}^3$ [15], current total surface area of 12.5 km^2 and an average depth of 7.7 m [16]. The area experiences 4 to 5 months short unimodal rainfall pattern and 7 to 8 months of the long dry season. The average annual rainfall is about 950 mm and that of temperature is 29°C [17].

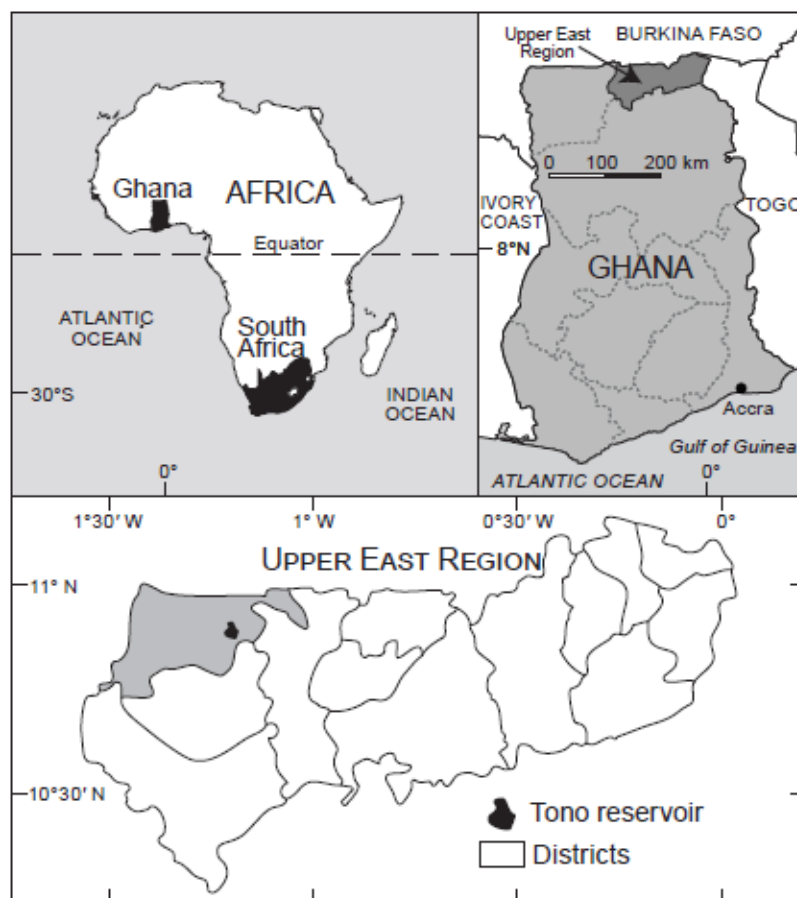


Figure 1. A map showing Tono Reservoir in the Upper East Region of Ghana. Source: [16]

Data Collection

Monthly fish samples were obtained using cast nets (2.5 cm mesh size) and gillnets (1.0 – 7.5 cm) for 24 months (January, 2015 – December, 2016). The fish were kept chilled in an ice chest immediately after capture and sent to the laboratory. At the laboratory, morphometric parameters (weight to the nearest 1.0 g and standard length to the nearest 0.1 cm) of specimen were measured and recorded. Fish were dissected and the digestive system removed and preserved in 4% formalin. In order to examine the food item, the stomach was then taken out by cutting the alimentary tract between the end of oesophagus and the pylorus. The content was emptied into petri dishes. The weight of the stomach plus content and weight of content only from each individual specimen were taken using a digital scale to the nearest 0.0001 g. Stomach content was first sorted by eye for larger food substances and secondly dispersed with small amount of distilled water; sub-samples were taken from the stock and observed and identified under a Celestron Digital LCD microscope at varying magnifications up to x 40. Food items were identified up to the genus level wherever possible using identification keys by [18] for zooplankton and [19] for phytoplankton.

The sex of each specimen was identified firstly by visual examination and later confirmed after dissection and examination of the gonads. The gonads were removed from the other visceral organs and weighed to the nearest 0.0001 g using electronic balance. Maturity stage was graded visually based on a five-point scale [20] and tabulated (Table 1). A blend of external features and eye examination of split open body cavity of specimen was carried out to identify sex of fish. Tubular, pink and granular sex organs were considered as ovaries while the organs with flat, white and wave-like ventral edges outline were considered as testes. The testes also had a more flattened knife-edged shape than the ovaries. The gonads were removed from the other visceral organs and weighed to the nearest 0.0001 g using electronic balance. Ovaries of stages II to IV were preserved in Gilson's and left for at least 24 hours for the eggs to be liberated from ovarian tissues after which the eggs were washed with 70 % ethanol [21].

Data analysis

Analysis of the data on gut contents was carried out using frequency of occurrence and numerical composition methods [22, 23]. Stomach contents were examined and the individual food organisms sorted and identified. The number of stomachs in which each item occurred was recorded and expressed as a percentage of the total number of stomachs examined as follows [22, 23]:

$$\text{Frequency of Occurrence (F)} = \frac{\text{Total no.of stomachs with particular food item}}{\text{Total no.of stomachs with food}} \times 100.$$

The total number of a particular food item was recorded and expressed as a percentage of total number of all food items during the study [22, 23]

$$\text{Numerical Method (N)} = \frac{\text{Total no.of particular food item}}{\text{Total no.of all food items}} \times 100.$$

The measures of frequency of occurrence (F) and number of food items (N) recorded in this study were integrated into an 'index of relative importance' (IRI) to determine the principal food item of the major fish species as:

$$\text{IRI} = F \times N \text{ [24]}$$

Mann-Whitney U test was performed to detect seasonal variation in food items consumed by the five fish species. Post-hoc analysis was done using Mann-Whitney U pairwise to identify differences in food items consumed by the fish species at $\alpha = 0.05$ significance level using Paleontological Statistics version 3.11 (PAST).

Fecundity expressed as the number of eggs laid in a single season by the species was estimated using Gravimetric method [25].

Table 1. Description of gonad maturity stages of fish

Stage	State	Description
0	Virgin	Very small gonads close under the vertebral column; testes and ovaries colourless; eggs invisible to naked eye.
I	Maturing virgin	Testes and ovaries translucent; small eggs can be seen with the aid of magnifying glass.
II	Developing	Ovaries reddish; eggs visible to eye. Testes appear as tiny processes or strands
III	Developed	Ovaries orange-reddish. Eggs clearly discernible. Ovaries occupy about two thirds of central cavity. Whitish milt appears under slight pressure.
IV	Gravid	Ovaries filling ventral cavity, eggs completely round and released from ovary with little pressure on abdomen. Testes conspicuously bulky and whitish with milt flowing when punctured.
V	Spent	Not yet fully empty. No opaque eggs left in ovaries; ovaries large but flabby. Testes flabby and with remains of milt.

Source: Adopted from [20]

The sex ratio was determined using the proportion of the number of males to that of the females that were sampled monthly. It was calculated as follows:

$$\text{Sex ratio (SR)} = \frac{\text{Number of males}}{\text{Number of females}}$$

Chi-square test was used to determine if a population contains equal proportions of males and females at $\alpha = 0.05$ significance level.

The gonadosomatic index (GSI) was estimated as the ratio of gonad mass to total body mass (a high value indicates a large investment in reproduction). The seasonal variation in the GSI was used to define the peak spawning periods, respectively. The GSI was calculated [26]:

$$\text{SI} = \frac{\text{Gonad weight (g)}}{\text{Fish weight (g)}} \times 100 .$$

The relationship between fecundity and standard length, weight of fish, and gonad weight were determined using multiple linear regression analysis at $\alpha = 0.05$ significance level.

Results

Food and feeding habits

Table 2 shows the list of food items found in the stomach of the five commercially important fish species namely *Auchenoglanis occidentalis*, *Clarias gariepinus*, *Oreochromis niloticus*, *Sarotherodon galilaeus* and *Coptodon zillii*. The relative contributions of the food items are expressed by frequency of occurrence, numerical method and index of relative importance (IRI). A total of 714 randomly selected specimens were examined with standard length ranging from 9.8 – 15.0 cm for *C. zillii* to 21.2 – 33.0 cm for *C. gariepinus* and weight ranging from 36.0 – 155.0 g to 101.0 – 256.7 g respectively. Thirty-three (33) major food items classified under phytoplankton, zooplankton, macrophyte, animal derivative and sand/detritus constituted the diet of the five fish species. Phytoplankton was the most important diet (IRI = 1923) with the highest frequency of occurrence whereas zooplankton was the least important (IRI = 35) with the lowest frequency of occurrence.

Table 3 presents the seasonal variation and correlation of food items found in the fish stomachs. There was no significant difference ($p > 0.05$) in food items found in the stomachs during dry and wet seasons for all the fish species except *S. galilaeus*. Correlation analysis showed that there was significant difference ($p < 0.05$) between food items found in the cichlids and *C. gariepinus* as well as *A. occidentalis* (Table 3).

Table 2. Checklist and relative contribution of food items found in the stomachs of five major fish species of the Tono Reservoir, Ghana for 2015 – 2016

Food item	Fish species					Freq. of occur. (%)	Number (%)	IRI
PHYTOPLANKTON								
Bacillariophyta (Diatoms)						25.0	10.1	253
Synedra sp.	—	—	iii	iv	v			
Gyrosigma sp			iii	iv	v			
Cyclotella sp		Ii	—	—	v			
Chlorophyta (Green algae)						23.1	8.7	201
Carteria sp.	—	—	—	iv	v			
Coelastrum sp	—	—	iii	iv	v			
Volvox sp	i	—	—	—	v			
Ankistrodesmus sp	—	—	—	iv	—			
Pediastrum sp	—	—	—	iv	—			
Stigeoclonium sp	—	Ii	iii	—	—			
Scenedesmus sp	—	—	iii	—	—			
Cosmarium sp	—	—	—	iv	—			
Schroederia sp	—	—	—	iv	—			
Staurastrum sp	—	—	iii	iv	—			
Cyanophyta (Blue-green algae)						40.4	26.0	1050
Anabaena sp.	i	—	iii	iv	v			
Microcystis sp.	i	Ii	iii	iv	v			
Pseudanabaena sp.	—	—	iii	iv	v			
Lyngbya sp.	—	—	iii	—	—			
Phormidium sp.	—	—	—	iv	v			
Chrysophyta						3.8	1.4	5
Surirella sp.	—	—	iii	iv	—			
Euglenophyta (Euglenoids)						1.92	0.7	1
Phacus sp.	—	—	iii	—	v			
Charophyta						0.96	0.7	1
Closterium sp.	i	ii	—	—	—			
Heterokontophyta						32.69	12.6	412
Tribonema sp	i	—	iii	iv	v			
ZOOPLANKTON								
Arthropoda (Phylum)						9.62	3.6	35
Polyphemus sp.	i	—	—	—	—			
Cypridopsis sp.	i	—	—	iv	v			
Chironomus sp.	—	ii	—	—	—			
Canthocamptus sp.	—	—	—	—	v			
Sida sp.	—	—	iii	—	—			
Rotifera						0.96	0.4	*
Brachionus sp.	—	—	iii	—	—			
MACROPHYTES						10.58	5.1	54
Plant parts	i	ii	—	iv	—			
ANIMAL DERIVATIVES						30.77	12.3	378
Worm	i	ii	iii	—	v			
Insect remains	i	ii	iii	iv	—			
Fish remains	i	ii	—	iv	v			
SAND/DETRITUS	i	ii	iii	iv	v	23.08	13.0	300
UNIDENTIFIED	i	ii	iii	iv	v	11.54	5.4	62
						n _{total} =104	N _{total} =277	

*Indicates IRI value < 0.1

n is total number of stomachs with food

N is total number of food items identified

– indicates absence of food item in fish stomach

i = *A. occidentalis*; ii = *C. gariepinus*; iii = *O. niloticus*; iv = *S. galilaeus*; v = *C. zillii*

Table 3. Seasonal variation and correlation of food items consumed by five major fish species of Tono Reservoir, Ghana from 2015 – 2016

A. Seasonal variation					
	<i>N</i>	Mean rank	Mann-Withn. <i>U</i>	<i>Z</i> -value	<i>P</i> -value
<i>S. galilaeus</i>					
Dry	12	8.732	117	-2.950	0.003*
Wet	44	19.768			
<i>O. niloticus</i>					
Dry	34	17.054	513.5	-0.172	0.863
Wet	31	15.946			
<i>C. zillii</i>					
Dry	29	14.745	317	-0.029	0.977
Wet	22	11.255			
<i>C. gariepinus</i>					
Dry	11	4.704	61.0	-1.358	0.174
Wet	16	9.296			
<i>A. occidentalis</i>					
Dry	30	16.218	102.5	-1.074	0.282
Wet	9	3.782			
B. Correlation of food items					
	<i>A. occidentalis</i>	<i>C. gariepinus</i>	<i>O. niloticus</i>	<i>S. galilaeus</i>	<i>C. zillii</i>
<i>A. occidentalis</i>		0.470	0.000*	0.000*	0.003*
<i>C. gariepinus</i>	0.470		0.000*	0.000*	0.001*
<i>O. niloticus</i>	0.001*	0.000*		0.141	0.967
<i>S. galilaeus</i>	0.000*	0.000*	0.141		0.200
<i>C. zillii</i>	0.003*	0.001*	0.967	0.200	

* Indicates *p*-values that are significant ($p < 0.05$)

Reproductive Characteristics

The overall sex ratio (male: female) of 714 specimens was 1.2:1.0. A chi-square test indicated significant difference ($p < 0.05$) for the sex ratios of *A. occidentalis* and *C. gariepinus* but showed no significant difference ($p > 0.05$) for *O. niloticus*, *S. galilaeus* and *C. zillii* from the expected 1:1 ratio (Table 4). The highest mean GSI was recorded in *S. galilaeus* and lowest in *C. gariepinus* (Table 4). The major peaks of GSI of females were noted in February – March and June – July (Fig. 2).

Table 4. Reproductive characteristics of five major fish species of the Tono Reservoir, Ghana in 2015 and 2016

	<i>S. galilaeus</i>	<i>O. niloticus</i>	<i>C. zillii</i>	<i>C. gariepinus</i>	<i>A. occidentalis</i>
Male: Female	1.3 : 1.0	1.0 : 1.0	1.0 : 1.1	3.1 : 1.0	2.8 : 1.0
<i>N</i>	2	2	2	2	2
<i>DF</i>	1	1	1	1	1
χ^2	1.203	0.023	0.343	12.086	15.899
<i>p</i> -value	0.273	0.879	0.558	0.000*	0.000*
Fecundity \pm S.D	511 \pm 161.7	472 \pm 145.7	444 \pm 163.6	1375 \pm 691.7	692 \pm 287.6
GSI \pm S.D.	2.80 \pm 1.96	1.93 \pm 1.27	2.54 \pm 2.32	0.38 \pm 0.27	0.56 \pm 0.62
SL range (cm)	8.4 – 14.5	9.8 – 15.0	9.8 – 15.0	21.2 – 33.0	16.0 – 31.0
Weight range (g)	28.0 – 129.0	42.0 – 119.0	36.0 – 155.0	101.0 – 256.7	80.0 – 835.0

*Indicates significantly different at $p < 0.05$

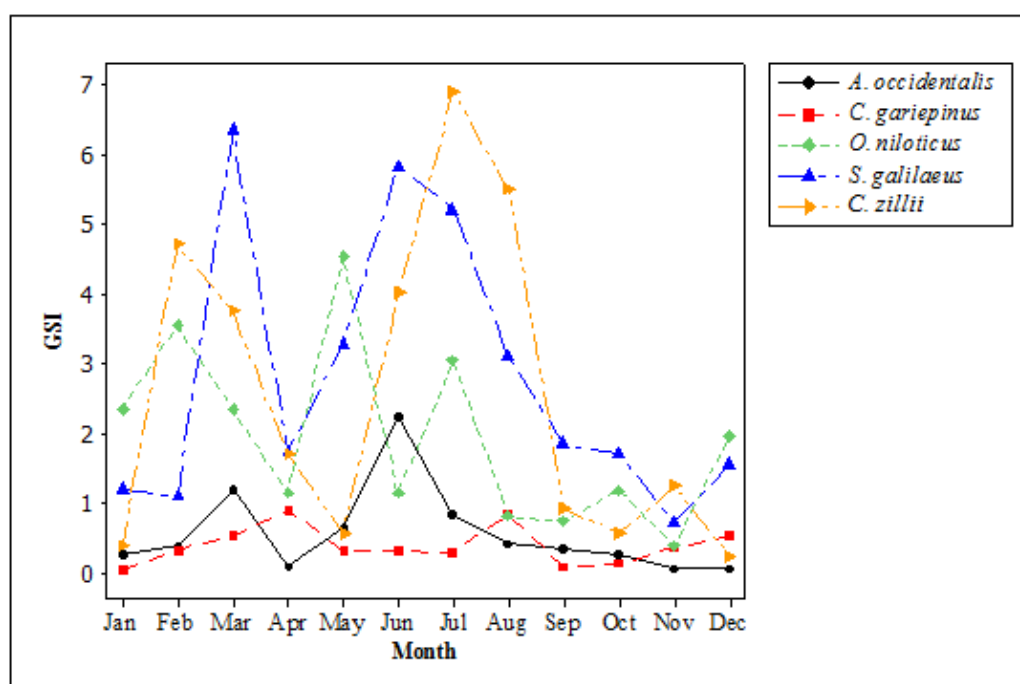
**Figure 2.** Monthly variation of gonadosomatic indices for females of five major fish species of the Tono Reservoir, Ghana in 2015 and 2016

Table 5 depicts the relationship between fecundity and independent variables namely standard length, fish weight and gonad weight of female specimens of *C. gariepinus* and *A. occidentalis*. The relationship between fecundity versus standard length, fish weight and gonad weight of female specimens determined by multiple linear regression was significant ($p < 0.05$) for both *C. gariepinus* and *A. occidentalis*. About 96.1% variation of fecundity was explained by the predictors (standard length, fish weight and gonad weight) for *C. gariepinus* whilst 89.3 % variation of fecundity was explained by the predictors for *A. occidentalis*. However, these same variables were poor predictors for *C. galilaeus*, *O. niloticus* and *C. zillii* with an R-square of 0.00 % and were excluded.

Table 5. Relationship between fecundity, standard length, fish weight and gonad weight of female specimens of *C. gariepinus* and *A. occidentalis* in the Tono Reservoir, Ghana in 2015 – 2016

<i>C. gariepinus</i>							
Predictor	Estimated Coefficient	SE Coefficient	T-statistic	p-value	R-Sq	R-Sq (adj)	R-Sq (pred)
Constant	-3296.30	464.0	-7.10	0.000	96.1 (%)	94.6 (%)	87.3 (%)
Standard length (cm)	178.71	29.27	6.10	0.000			
Fish weight (g)	0.97	2.32	0.42	0.687			
Gonad weight (g)	15.0	116.4	0.13	0.901			
<i>A. occidentalis</i>							
Constant	-419.90	233.70	-1.80	0.110	89.3 (%)	85.3 (%)	76.73 (%)
Standard length (cm)	58.52	13.09	4.47	0.002			
Fish weight (g)	-1.53	0.27	-5.76	0.000			
Gonad weight (g)	183.09	40.23	4.55	0.002			

Discussion

Food and feeding habit

The food composition of the five fish species in the Tono Reservoir was indicative of a high food richness as the specimens exhibited high trophic flexibility by the broad spectrum of food items consumed. The food of the fish species varied from microscopic substances such as plankton to macroscopic items such as macrophytes and animal derivatives. Food items consumed by *A. occidentalis* and *C. gariepinus* were similar but differed from that of the cichlids. Plankton was noted as the major food of the cichlids but they also had a strong tendency towards plant parts and animal derivative making them omnivores. The results were similar with that of [27] in Nigeria and [28] in Abu-Zabal Lakes, Egypt but contradicted that of [29] who classified them as planktivores. The high trophic plasticity exhibited by cichlids in the current study explains well their survival and resilience despite the sustained fishing pressure on the reservoir. *Auchenoglanis occidentalis* consumed mainly detritus/sand, plant parts and animal derivatives; an indication of benthic omnivore and agreed with the work done in Lake Akata, Nigeria by [30]. Similarly, the food of *C. gariepinus* was not much different from *A. occidentalis* making it an omnivorous scavenger. This result corroborated with the results of [29].

The diet preference of the fish species except *S. galilaeus* did not vary significantly with seasons attributable to the lack of any considerable seasonal food inputs into the reservoir. The results for *S. galilaeus* contradicted that of [31] who observed no seasonal variation of diet in Lake Bosumtwi, Ghana. *S. galilaeus* was noted to spawn continuously in the wet season beginning from May to September and this could have accounted for the seasonal variation of food consumed.

Reproductive characteristics

The results indicated the dominance of males over females. The reason for the male dominance could be that males move away from areas of spawning to where they are captured once fertilization of eggs is established while the females probably go towards submerged vegetation and other areas around the reservoir to evade predators and also continue brooding and protection of the offspring. Related results were observed by [32] for two dominant fish species in Ado reservoir, Southwest Nigeria. The peaks which were observed in GSI indicated that the fish species spawned at least once

in a breeding season. This agreed with [33], who stated that *O. niloticus* breeds more than once in a season. Furthermore, the GSI of the fish species revealed seasonal variations indicating different spawning intensities for different seasons. The lowest GSI in general was obtained during the dry months (November–April), which constituted the low water level period. Conversely, the peaks happened during the rainy months (May – October), which formed the inundation period conforming to the peaks of the recruitment patterns of the species. This result corroborated with that of [34] for the Bontanga reservoir.

The difference in fecundity noted in this current study is typical in fish [35] and the number of eggs produced by an individual female is influenced by the size, age, health status, availability of food and space [36]. The effect of standard length, fish and gonad weight on fecundity was significant ($p < 0.05$) for both *C. gariepinus* and *A. occidentalis*. The regression results showed that the variations of fecundity of *C. gariepinus* (96.1 %) and *A. occidentalis* (89.3 %) were largely explained by standard length, fish and gonad weight leaving the remaining 3.9 % and 10.7 % variation respectively to extraneous parameters not specified in the regression model.

Conclusions

The food and feeding habits indicated that all five fish species were omnivores. Cyanophyta (Blue-green algae) were noted to be the most important food item for the five fish species. All the five fish species spawned more than once in a year, suggesting their dominance in the reservoir. This study also showed that standard length, fish and gonad weight affect the number of eggs produced per spawning of *C. gariepinus* and *A. occidentalis*.

Conflict of Interest

There is no conflict of interest regarding this article.

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