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SOME ASPECTS OF BIOLOGY AND DIGESTIVE ENZYMES ASSAY IN THE GASTROINTESTINAL TRACT OF CHRYSICHTHYS SPECIES IN LOWER OGUN RIVER, OGUN STATE, NIGERIA

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ABSTRACT

Fish and other aquatic foods represent an important source of food to man, highly rich in most essential nutrients such as protein and vitamins. Aspects of the biology and digestive enzymes assay in the gastrointestinal tract of two congeneric Chrysichthys species were analyzed from July to December 2019 in the lower Ogun river, Akomoje, Ogun State, Nigeria. A total of fifty-three each of Chrysichthys nigrodigitatus and Chrysichthys auratus caught with traps were used during the study. Data were statistically analyzed. Mean standard length, body weight, stomach girth and gape width for Chrysichthys nigrodigitatus and Chrysichthys auratus were 18.39±4.46cm and 15.07±2.36cm; 174.29±102.71g and 88.16±37.62g; 11.9±2.94cm and 10.22±1.75cm; and 1.89±1.09cm and 1.68±0.29cm, respectively. Mean sex ratio in favour of the males were 1:0.36 and 1:0.33, respectively which were significantly ($p< 0.05$) different from the hypothesized ratio of 1:1. C. nigrodigitatus and C. auratus both exhibited a negative allometric growth pattern during the study period with a b-value of 2.97 and 2.32; mean condition factors were 1.33 and 0.92 for C. nigrodigitatus and C. auratus, respectively. The prey items found in the stomach of these congeneric species were similar and comprised thirty-three species which can be categorised into seven groups: Algae (8.5% and 11.8%,), Protozoans (22.1% and 18.9%), Desmids (5.3% and 6.3%), Diatoms (13.5% and 11.9%), Rotifers (4.8% and 6.7%), Invertebrates (8.4% and 0.8%) and Crustaceans (21.2% and 26.3%) respectively. Other prey items include detritus, mud/sand, fish parts and other unidentified items. Protozoans (22.1%) and Crustaceans (21.2%) dominated the food items for C. nigrodigitatus and C. auratus while detritus (2.13%) and invertebrates (0.84%) constituted the least component of food items for the two fish species, respectively. The specific activities of some enzymes (proteases, carbohydrase, and lipase) along the gut region (stomach, mid-gut and hind-gut) of these two Chrysichthys species were also studied; the mean values of population of these enzymes were significantly ($P<0.05$) different across the alimentary tract. The distribution pattern of the enzymes showed that both C. nigrodigitatus and C. auratus were capable of digesting protein, carbohydrate, and lipid components of their food. These findings further corroborate their trophic niche as indicated in their feeding habits. Further studies are recommended on the seasonal distribution of enzyme activities to ascertain the nutritional physiology of these economically important fish species in the study area.

Keywords: Condition factor, Degree of fullness, Enzyme activity, Growth pattern, and Lipase.

INTRODUCTION

Fish accounts for more than 40% of the protein diet of two–thirds of the world population (Esenowo et al., 2017); hence the reason for the high demand for these aquatic products. Unfortunately, the protein requirement of most African countries still conspicuously outweighs its supply. In Nigeria, less than 40% of the total protein required by the people is met, of which 41% is enacted by fish (Bernard et al., 2011). Despite the various nutritional and economical importance of these seafoods, the state of fish stock on the global scale is declining at an alarming rate due to the cumulative effect of environmental degradation, anthropogenic activities and overfishing pressure (Ojelade et al., 2019). Thus, there is an urgent need to conserve these economically important fish species to prevent their subsequent collapse.

Chrysichthys nigrodigitatus and Chrysichthys auratus are fish species without any strict feeding habits (Esenowo et al., 2017). Several researches have been conducted on the food and feeding habit of these fish species (Idodo-Umeh (2002), Oronsaye and Nakpodia (2005) and Offem et al (2008). The ability of a fish species to digest a food substance adequately depends wholly on the digestive enzymes along the degradation pathway/alimentary tract of that fish among other factors (Caruso et al., 2009). The qualitative and quantitative assessment of enzymatic activity represents an important scientific way of providing appropriate information on the nutritional physiology of the species (Fagbenro et al 2005). The result of the activities of enzymes along the gut can also be used to corroborate the relationship between the food and the feeding habit of a fish and its trophic niche. However, there is still paucity of information on the digestive enzyme assay of these species in Lower Ogun River, Ogun State, Nigeria. Thus, this study provides basic information on some aspects of biology and digestive enzyme assay of two congeneric fish species in the lower Ogun river, Ogun State, Nigeria.

Study area

The study was carried out at the lower Ogun River, Akomoje in Abeokuta, Nigeria. Ogun River is located in Abeokuta North Local Government of Ogun State. It is one of the major rivers in Southwestern Nigeria with a total area of 22.4km² and a fairly large flow of about 393m³/s during the wet season (Oketola et al., 2006). It has coordinates of 3°28"E and 8°41"N from its source in Oyo State to 3°25"E and 6°35"N in Lagos where it enters the Lagos lagoon (Ayoade et al., 2004) (Figure 1). A dry season from November to March and a wet season between April and October are the two seasons distinguishable in Ogun River Basin. Mean annual rainfall ranges from 900 mm in the North to 2000 mm in the South. The estimates of total annual potential evapotranspiration have been put between 1600 and 1900 mm (Bhattacharya and Bolaji, 2010). The water is used for agriculture, transportation, human consumption, various industrial activities and domestic purposes. It also serves as a raw material to the Ogun State Water Corporation which treats it before dispensing it to the public. Along its course, it constantly receives effluents from breweries, slaughter houses, dyeing industries, tanneries, domestic wastewater and locust beans processors before finally discharging to Lagos lagoon. A 100km² area around River Ogun has an approximate population of 3,637,013 (0.03637 persons/m²) and an average elevation of 336m above the sea (Travel Journals, 2012).

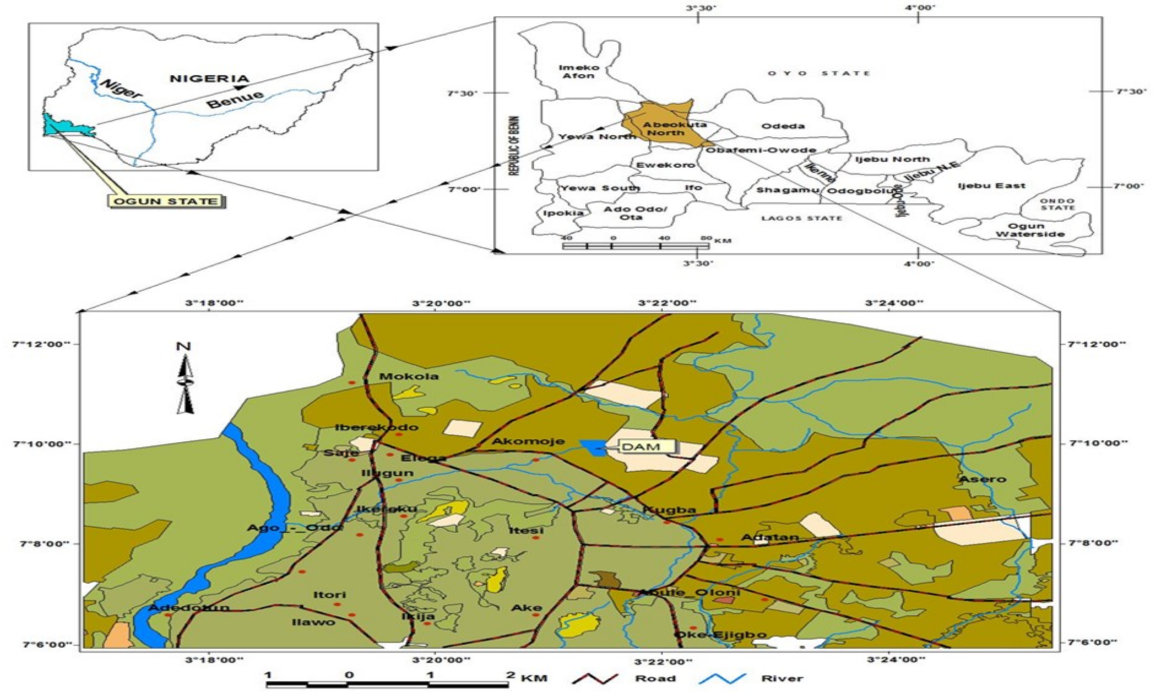

Figure 1: Lower Ogun River, Akomoje, Ogun State, Nigeria.
Source: Field Survey, 2019.

Fish collection and handling

Samples of C. nigrodigitatus and C. auratus were collected from commercial fishermen at Akomoje landing site of the lower Ogun river between July and December 2019. A total of 53 samples of each of the fish species were caught with set traps placed along the river bank where the fish seeks refuge. Fish samples of various sizes were collected immediately after capture, sorted into species and transported live to the wet laboratory of the Department of Aquaculture and Fisheries Management, FUNAAB. The fish specimens were identified using guides provided by Reed et al. (1967), Olaosebikan and Raji (1988), and Idodo- Umeh (2003). Measurements of morphometric characters were taken on the left side of the fish with a measuring board to the nearest 0.1cm. Total length (TL) was measured from the tip of the snout with the mouth closed to the extended tip of the caudal fin, Standard length (SL); was measured as the body distance from the tip of the snout with the mouth closed to the base of the caudal fin, Stomach girth (SG); measured with a tape ruler around the fattest part of the fish, Mouth depth (MD); measured as the depth in the dorsal-ventral direction of the maximum opening of the mouth of the fish, Gape width (GW); measured as the distance between the angles of the closed mouth. Fish body weight was measured in grams (g) using a sensitive scale (Model: EK5350). The sex of each specimen was determined after dissection based on the presence of testes or ovaries, the gastrointestinal tract (GIT) was gently removed and its maximum length without convolution was measured on a measuring board. The weight of the GIT to the nearest 0.1g was also recorded using a sensitive scale. The stomachs were carefully removed and preserved separately in 4% formalin solution in labelled sampling bottles prior to analysis in the wet laboratory of the Aquaculture and Fisheries Department.

Stomach content identification

Samples of the two fish species were anaesthetized with MS222 and examined individually. Each stomach was visually assessed and documented for the degree of fullness (0/4=empty, 1/4=one quarter full, 2/4= half full, 3/4= three quarter full, 4/4= full stomach), according to methods described by Ugwumba and Ugwumba, (2007). Fish species with three-quarter full and full stomachs were dissected and subjected to further analysis. The stomach content of each specimen was dissected lengthwise and emptied into a petri-dish for examination. Each stomach content was dispersed with distilled water; sub-samples were taken from the stock and observed under a microscope. Direct enumeration and identification were performed to the genius level using a microscope connected to a camera (Premier equipped model) at ×4μm and ×10μm magnification. Identification was done using guides provided by Newell and Newell (1977); Maosen (1978), Egborge (1973) and Mellanby (1975).

Frequency of occurrence of food items

The frequency of prey items observed in each of the stomachs were enumerated and expressed as a percentage of the total number of stomachs with food (empty stomachs excluded). This method gives a precise evaluation of the food spectrum of the species. Hence, the importance of the food items relative to the population of the species could probably be guessed.

$$F1 = 100 * \frac{fi}{n}$$

Where

F1: frequency of occurrence of the i food item in the sample

fi: number of stomachs in which the i item is found

n: number of stomachs with food in the sampled

Sex ratio

The number of identified males and females of Chrysichthys species were recorded and used to determine the sex ratio from the naturally hypothesized ratio of 1:1. This was done using the formula:

Sex ratio = number of males/number of females (Ojelade, et al., 2019).

Growth pattern of the Chrysichthys species

The length-weight relationship was determined using

$$W = aL^b$$

Where

W = Body weight in grams

L = Total length of fish in centimeters

a = Intercepts

b = Growth exponent or regression coefficient

'a' and 'b' are constants and their values were estimated from the log-transformed relationship of length-weight below. 'b' was used to determine the growth pattern of the fish at 95% confidence limit.

$$Log\ W = \log a + b \log L$$

The obtained length-weight relationships were interpreted according to Abdul et al., (2016), when 'b' value equal to 3, it implies that the fish exhibits an isometric growth pattern while b values less than or greater than 3 indicates a positive or negative allometric growth (Froese, 2006).

The condition factors of the Chrysichthys species

The condition factor (K) was estimated using Fulton's equation expressed as:

$$K = \frac{(100\ x\ W)}{Lb}$$

Where;
K = Condition factor
W = Weight of fish (g)
L = Standard length of fish (cm)
b = Growth exponent from LWR

Digestive Enzyme Analysis

The weighed alimentary tracts of the anaesthetized congeneric fish species were carefully removed to anatomically identify the stomach, mid and hind-gut of the fish specimen distinctively for the enzyme analysis. The different gut regions were pooled and homogenized, homogenates were centrifuged at 1200rpm for 30 minutes at 40C. Qualitative and quantitative assays of Carbohydrase were conducted using methods of Olatunde et al (1988) and Plummer (1978) as reported in Fagbenro et al (2000). Proteases and lipases were estimated using the methods of Balogun and Fisher (1970) and Ogunbiyi and Okon (1976) as reported in Chaudhuri et al (2012).

Statistical Analysis

All data collected were subjected to statistical analysis using descriptive and inferential statistical tools.

RESULTS

Morphological parameters and the sex ratio of the fish species

Out of the total 53 samples each of C. nigrodigitatus and C. auratus sampled from lower Ogun river during the study period, the mean total length recorded for both species were 23.77±5.96cm and 19.73±3.08cm with a corresponding mean body weight of 174.29±102.71g and 88.16±37.62g, respectively (Table 1). The gape width ranged between 0.80cm to 3.21cm for C. nigrodigitatus and 0.70 to 2.10cm for C. auratus respectively, with a mean gut length of 49.0±8.99cm and 44.09±6.46cm, respectively. The obtained male to female ratio of C. nigrodigitatus (1:0.36) were not significantly ($p>0.05$) different from that of C. auratus (1:0.33) with a chi-square value of 0.25 and 2.89, respectively (Table 2).

Table 1: Summary of morphological parameters of two congeneric fish species from the lower Ogun river

	C. nigrodigitatus		***C. auratus***	
Morphological parameters	**Range**	**Mean±S.D**	**Range**	**Mean±S.D**
Total Length(cm)	13.40-36.60	23.77±5.96	15.9-26.54	19.76±3.08
Standard Length(cm)	10.20-28.93	18.39±4.46	12.0-22.10	15.07±2.36
Body weight(g)	50.23-390.7	174.29±102.71	47.2-198.60	88.16±37.62
Stomach Girth(cm)	6.35-20.91	11.9±2.94	7.30-14.50	10.22±1.75
Mouth Depth(cm)	0.32-2.85	1.74±0.65	1.60-2.70	2.01±0.26
Gape Width(cm)	0.80-3.21	1.89±1.09	0.70-2.10	1.68±0.29
Gut Weight(cm)	0.13-3.97	1.89±1.10	1.84-4.50	3.04±0.88
Gut Length(cm)	17.6-61.93	49±8.99	30.4-54.32	44.09±6.46

Source: Field survey, 2019

Table 2: Chi-square ($\chi 2$) analysis of male to female sex ratio of *C. nigrodigitatus* and *C. auratus*

Species	Frequency	Male	Female	Sex Ratio	Chi-square value (χ^2)
C. nigrodigitatus	53	39	14	1:0.36	0.25
C. auratus	53	40	13	1:0.33	2.89*

*Values not significantly different at 95% confidence limit

Growth parameters and Fulton's condition factor of the fish species

The samples of C. nigrodigitatus and C. auratus used during the study period both exhibited a negative allometric growth pattern with b-value of 2.98 and 2.32 respectively. However, the condition factor obtained for both species of fish were 1.33 and 0.92 respectively as indicated in Table 3.

Table 3: The condition factor (k) and growth pattern of *C. nigrodigitatus* and *C. auratus* in lower Ogun River, Akomoje.

	Condition factor (k)	a	b	r^2	Length-weight relationship
C. nigrodigitatus	1.33	0.5235	2.9765	0.7126	LogW=1.9765LogL - 0.524
C. auratus	0.92	1.0813	2.3198	0.8812	LogW=2.3198LogL - 1.081

Source: Field survey, 2019

Degree of fullness

The degree of fullness of the fifty-three fish species each of C. nigrodigitatus and C. auratus is presented in Figure 2. 90.6% of C. nigrodigitatus had full stomach while 71.7% of C. auratus had three-quarter full stomach. Only two (2) and eleven (11) stomachs each out of the 53 sampled stomachs were empty (0/4) as indicated in fig 2.

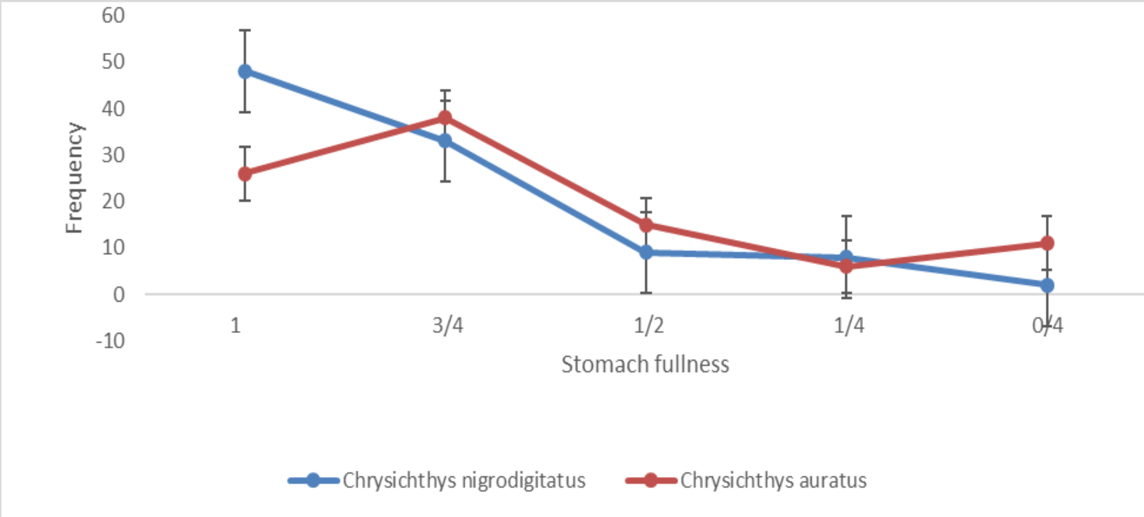

Figure 2: Degree of stomach fullness of *C. nigrodigitatus* and *C. auratus*

Stomach content

Thirty-three different prey categories were recorded in the stomachs of the two congeneric fish species. The food composition of C. nigrodigitatus and C. auratus included seven groups: five (5) species of Algae, six (6) species of Protozoans, six (6) Desmids, three (3) Diatoma, one (1) Rotifers, three (3) invertebrates and five (5) species of Crustaceans (Table 4). Other prey items include sand, detritus, some fish parts, and unidentified items. For C. nigrodigitatus, 22.07% of the prey items were found to be Protozoans, followed by Crustaceans which constituted 21.17% while Detritus had the least frequency of occurrence with a percentage of 2.13%. However, in the stomach content of C. auratus Crustaceans had the highest preponderance of occurrence with an average of 26.26%, followed by protozoan and diatoms with a percentage occurrence of 18.9% and 11.97% respectively while the invertebrates had the least frequency of occurrence with a percentage of 0.84% (Table 4).

Table 4: Percentage frequency of occurrence of food items found in the stomach of *Chrysichthys nigrodigitatus* and *C. auratus*

		Chrysichthys nigrodigitatus		***Chrysichthys auratus***	
		Frequency	**Percentage**	**Frequency**	**Percentage**
Algae	*Closterium*	*15*	2.67	9	1.89
	Spirogyra	10	1.78	11	2.31
	Polycystis	6	1.07	15	3.15
	Tetraspora	8	1.42	3	0.63
	Microspora	9	1.60	18	3.78
	Sub-total	**48**	**8.54**	**56**	**11.76**

Protozoans	*Paramecium*	32	5.69	29	6.09
	Chlamydomonas	12	2.14	15	3.15
	Pleodorina	29	5.16	11	2.31
	Chilodonella	20	3.56	2	0.42
	Yorucella	19	3.38	0	0
	Loxodex	12	2.14	33	6.93
	Sub-total	**124**	**22.07**	**90**	**18.9**
Desmids	*Genicular*	8	1.42	2	0.42
	Closterium	5	0.89	0	0
	Desmidium	1	0.18	0	0
	Penium	2	0.36	1	0.21
	Docidium	7	1.25	27	5.67
	Tetmemorous	7	1.25	0	0
	Sub-total	**30**	**5.33**	**30**	**6.30**
Diatom	Diatoma	24	4.27	15	3.15
	Stephanodiscus	35	6.23	42	8.82
	Tabellaria	17	3.02	0	0
	Sub-total	**76**	**13.52**	**57**	**11.97**
Rotifers	*Rotaria*	27	4.80	32	6.72
	Sub-total	**27**	**4.80**	**32**	**6.72**
Invertebrates	Flatworm	21	3.74	0	0
	Nematode	16	2.85	3	0.63
	Chaoborus larvae	10	1.78	1	0.21
	Sub-total	**47**	**8.37**	**4**	**0.84**
Crustaceans	Magaritifera	41	7.29	34	7.14
	Corophnium	23	4.09	28	5.88
	Daphnia	19	3.38	16	3.36
	Povilla	0	0	2	0.42
	Neomysis	36	6.40	45	9.45
	Sub-total	**119**	**21.17**	**125**	**26.26**
Others	Sand	43	7.65	25	5.25
	Detritus	12	2.13	18	3.78
	Fish parts	22	3.91	31	6.51
	Unidentified items	14	2.49	8	1.68
	Sub-total	**91**	**16.19**	**82**	**17.23**
		562		476	

Source: Field survey, 2019

Digestive Enzyme Assay

Species of C. nigrodigitatus and C. auratus presented moderate carbohydrase activity in the stomach with mean values of 23.4±0.00 and 27.14±1.86, respectively (Table 5), while the least value of carbohydrase activity was observed in the hind-gut (11.5±0.00 and 12.7±1.01). A relatively higher protease activity was observed along the entire gut region of the two congeneric fish species with mean values of 48.63±0.59 and 35.2±0.99 in the stomach of C. nigrodigitatus and C. auratus respectively. There were no significant ($P<0.05$) differences in the obtained mean values of the enzymatic activities along the entire gut region during the study period. Meanwhile, the alimentary tract of both fish species exhibits the lowest lipase activity irrespective of digestive organs. Lipase activity was at minimum levels in C. nigrodigitatus and C. auratus, however, activity of lipase was not found in the hindgut of C. nigrodigitatus with the highest mean value of 11.93±4.81 recorded in the stomach region of the fish species. Maximum and minimum lipase activity was recorded in the stomach and hind-gut of C. auratus with mean values of 12.9±2.64 and 6.35±1.93, respectively (Table 5).

Table 5: Comparative illustration of enzymatic activities of two congeneric fish species among digestive organs (stomach, mid and hindgut) from lower Ogun river, Ogun State, Nigeria.

	Stomach	Mid-gut	Hind-gut
Chrysichthys nigrodigitatus			
Carbohydrase[1]	23.4±0.0019[ab]	13.8±0.0021[a]	11.5±0.0011[c]
Proteases[2]	48.63±0.5901[a]	31.51±0.4319[b]	25.64±0.2973[c]
Lipase[3]	11.93±4.81[b]	9.6±1.97[a]	ND
Chrysichthys auratus			
Carbohydrase[1]	27.14±1.86[b]	19.32±1.19[ab]	12.7±1.01[bc]
Proteases[2]	35.2±0.99[bc]	23.6±0.86[a]	18.4±0.53[ab]
Lipase[3]	12.9±2.64[ab]	10.8±2.09[abc]	6.35±1.93[a]

Values (Mean ± standard deviaion) in the same row with dissimilar superscripts are significantly different ($P= 0.05$); ND = not detected, [1] mg glucose/min/mg protein at 37 ^oC, [2] change in optical density at 595 nm/hr/ mg of L-tyrosine/hr at 37 ^oC, [3] milliequivalents of fatty acids/ mg protein/hr at 37 ^oC t

DISCUSSION

The obtained range of standard length and body weight for C. nigrodigitatus and C. auratus in the lower Ogun river during the study period is similar to the findings of Atobatele and Ugwumba (2011) who reported a maximum standard length of 25.6 cm and 19.8 cm; and a weight of 288.7g and 19.8 cm respectively in Aiba Reservoir. However, the values obtained in this study were smaller compared to the report of Idodo-Umeh (2003) who worked on both congeneric fish species in River Ase in Delta state, where higher values of maximum standard length and body weight were recorded. This disparity in morphological parameters could be attributed to intense fishing activities, anthropogenic effects and dwindling fish stock militating the fish population structure in the study area (Offem et al. 2008, Ojelade et al., 2019).

Most of the species of C. nigrodigitatus (73.6%) and C. auratus (75.5%) used in this study were males; this could be as a result of habitat preference, fishing location or spatial separation of both species for convenient trophic niche and reproductive strategy (Oronsaye and Nakpodia 2005; Yem et al. 2009). These findings are similar to the report of Offem et al (2008) on C. nigrodigitatus in Cross River who reported the same pattern of male domination which was attributed to the fact that the gears used were not set close to the breeding ground as males possibly emigrate from spawning areas to feeding grounds located in the shallow part of the water body where they were captured (Atobatele and Ugwumba, 2011). However, the observed sex ratio in favour of males further suggest that their female counterpart might have gone to submerged vegetation, rocky areas and possibly breeding grounds to escape the fishermen's trap and gears.

The length-weight relationship (LWR) of a fish species represents an important biological tool to predict the welfare and environmental condition of their habitat. The LWR of the examined Chrysichthys species showed a positive relationship between their lengths and body weights with a corresponding positive correlation as observed in the coefficient of determination (r2) values for C. nigrodigitatus and C. auratus, respectively. The obtained b-values imply that their body weight was increasing with an increase in total length (Abowei and Ezekiel, 2013). This result further showed that the fish species exhibited a negative allometric growth pattern which was not statistically different from the isometric growth pattern when statistically analysed with students' t-test to ascertain if the fish species grew isometrically or otherwise. However, the obtained b-value in this study is in agreement with the postulation of Pauly and Gayanilo, (1997) and also similar to the range of 2 - 4 mostly reported for tropical fish species (Thomas et al. 2003; Ogunola et al., 2018). Although, the result of this study contradicts a b-value greater than 3 reported in similar studies by Abowei and Ezekiel (2013) and Kareem et al., (2016) in Amassoma River flood plains and Lake Eleyele respectively. However, variations in the growth pattern of fish could be attributed to different sampling periods, sampling locations (fishing area or habitat) and environmental factors among others (Ogunola et al., 2018).

The condition factor (k) of a fish species represents its general well-being in its aquatic habitat; thus, it provides reliable information on the environmental suitability and welfare of inhabiting organisms. Bagenal (1978), as reported in Ogunola et al., (2018) opined that fish with higher K values (> 1) is in a better condition than fish with lower K values (< 1). However, the k-values of 1.33 and 0.92 obtained for C. nigrodigitatus and C. auratus in this study implies that both species, especially the former were in good condition during the sampling period in the lower Ogun river. The result of this study corroborates the findings of Abdul et al., (2016) and Ojelade et al., (2019) who reported similar k-values at Ogun coastal estuary and Ogun marine water along the bight of Benin respectively.

The prey items of C. nigrodigitatus and C. auratus encountered in the stomach of the sampled fish species showed that they fed on a variety of food substances such as crustaceans, protozoans, desmids, algae, diatoms, invertebrates, and fish parts among others. The observed rich items ingested by this fish species indicate that they are omnivorous bottom feeders with great trophic flexibility that can switch from one food item to the other in response to food availability (Thomas and Ogamode, 2019). A similar pattern of omnivorous trophic niche has been reported for Chrysichthys species by Oronsaye and Nakpodia (2005), Offem et al., (2008), Yem et al., (2009), Atobatele and Ugwumba (2011) and Ojelade et al., (2019). The food items documented in this study further revealed that C. nigrodigitatus and C. auratus had a similar feeding pattern with Protozoans and Crustaceans dominating their diet items in terms of frequency of occurrence. This observed trend of feeding pattern suggests an interspecific relationship between these two congeneric fish species. Thus, the species can feed across the entire water column and switch food content with respect to prey abundance and availability; this result further corroborates the findings of Esenowo et al., (2017) who reported that C. nigrodigitatus in Nwaniba River are omnivorous fish species that can feed on a wide spectrum of food substances. Idodo-Umeh, (2002) reported that the feeding intensity of a fish species can be determined using the degree of fullness of their stomachs. The relatively low percentage of empty stomachs recorded in this study indicates the diverse availability of prey items for these congeneric fish species in the lower Ogun river and could also be attributed to the fact that Chrysichthys species are frequent feeders (Oronsaye and Nakpodia, 2005). This observed pattern of the low percentage of empty stomachs corroborates the findings of Yem et al., (2009) and Atobatele and Ugwumba (2011) who worked on the feeding habits of Chrysichthys species at Kainji lake and Aiba reservoir of Nigeria, respectively. However, this finding contradicts the report of Esenowo et al., (2017) who attributed their observed high percentage of empty stomachs to the low quantity of food during the study period.

Kanou et al., (2000) and Chaudhuri et al., (2012), opined that the analysis of the digestive enzyme activities of a fish species represents an effective tool for identifying the components of an animal's diet, while Fagbenro et al., (2005) pointed out that digestive enzymes assay will ascertain the nutritional physiology of a fish. The observed high activity of proteases and carbohydrase in these two Chrysichthys species further affirm their omnivorous trophic niche which the stomach content revealed. This study is in agreement with the reports on enzymatic digestive activities depending on feeding habits (Chan et al. 2004; Corrêa et al. 2007). The relatively high value of proteases recorded in this study, especially in the stomach and mid-gut of these two fish species is not surprising in view of the large proportion of protein components in their diet. Thus, this observed high value is of great importance in their digestion of crustaceans which represents a bulk percentage of their stomach items. This finding is in line with the report of Cazorla and Forte (2005) and Fagbenro et al., (2005) who reported similarly high levels of proteases activities for some carnivorous fish species in Ogbese and Ose rivers in southwestern, Nigeria. The trend of carbohydrase activity found in the gut region of these two congeneric fish species indicates their ability to digest a wide range of carbohydrate food components. There was a lower activity of lipase along the entire gut region of the two fish species, moreover, lipase activity was not found in the hindgut of C. nigrodigitatus during the study period. The absence of lipase activity in some parts of the gut content suggests limited consumption of oily-related foods by these fish species, however, this contradicts the findings of Deng et al., (2010) and Xiong et al., (2011) who found the activity of lipase along the entire gut region of the studied fish species. In addition, there were no significant ($P>0.05$) differences in the mean values of all the analysed digestive enzymes in the alimentary tract of C. nigrodigitatus and C. auratus in lower Ogun river, Akomoje, Ogun State, Nigeria.

CONCLUSION

C. nigrodigitatus and C. auratus from the lower Ogun river exhibited a negative allometric pattern with a relatively good condition factor. They utilize a broad range of dietary items. C. nigrodigitatus and C. auratus in the Ogun river are well equipped to digest the carbohydrate, protein, and lipid components of their food items, hence they can be categorised as an omnivore in the trophic niche. Thus, this study recommends that further investigations on digestive enzyme activities in both wet and dry seasons should be carried out to ascertain the trophic niche of these fish species to improve the existing knowledge on fish nutrition physiology which offers an interesting and promising applicative purpose for aquaculture development.

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