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Biometric indices of *Clarias gariepinus* and *Oreochromis niloticus* in selected Gongola river corridors in Gombe State, Nigeria

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ABSTRACT
The length-weight relationship and organosomatic indices, are useful metric for detecting chronic stress in fish within aquatic ecosystems. The biometric indices of *Clarias gariepinus* and *Oreochromis niloticus* collected from the Gongola river corridors in Gombe State were investigated. Fish weight, standard and total length, the weigth of the liver, spleen and gonads were all measured and record. Moreover, Fulton condition index, Hepatosomatic index (HSI), splenosomatic index (SSI) and gonadosomatic index (GSI) were calculated using standard methods. All the mean concentrations obtained in the reference dam had condition factor <1 and this may be attributed to the over exploitation of the large size fish species of *C. gariepinus* and *O. niloticus* because of the high clarity of the water. Most fish samples collected from Gwani were found to be in good healthy stage. The highest HSI mean value was 0.98±0.82% indicating that these specimens from all the study areas were all < 1 because the study species were under stress due to high amount of rainfall in wet season. 2.47±4.04% was the highest GSI mean concentration of *O. niloticus* found in dry season at Gwani sampling locations showing elevation in body weight. This study also recorded low SSI mean values of 0.05±0.03% (0.05%) and 0.07±0.12% (0.07%) in *O. niloticus* and *C. gariepinus* at Balanga (the reference) dam and the variations in the morphology of spleen between species may be responsible for the low values of SSI. There were slight changes the biometric condition which may result from the stress conditions, suggesting a more comprehensive health assessment index in future research of the sampling sites.

Keywords: Biometric indices; Condition factor, Hepatosomatic index, Splenosomatic index; Gonadosomatic index; Gongola river corridors

INTRODUCTION
Aquatic ecosystems are vulnerable to significant contamination from various anthropogenic sources, including domestic and industrial sewage, as well as agricultural activities. Fish, being common bioindicators of environmental pollution, are directly impacted by these contaminants (Manzoor *et al.*, 2020). The interaction of multiple stressors in these environments can lead to complex effects on detoxification mechanisms, the accumulation of pollutants, and the onset of inflammatory reactions, oxidative stress, and cellular damage. The specific consequences vary depending on the combination of stressors present (Segner *et al.*, 2014).

Biometric indices, also known as condition indices, provide insight into the overall health status of fish based on organ mass (Petitjean *et al.*, 2020).

These indices of stress encompass various metrics such as length-weight relationship, organosomatic indices, and necropsy (Iwanowicz *et al*., 2018; Barton 2002), which are valuable for detecting chronic stress in fish within aquatic environments. Many condition-related measures involve straightforward assessments of weight (either of the entire organism or specific organs), length, or both. Organosomatic indices, such as the ratio of organ weight to body weight, are commonly utilized as indicators of stress and condition due to their simplicity (Rabson *et al*., 2017).

Activities occurring upstream of the selected sites within the Gongola River may influence the overall health conditions of the sampling species of this research. The activities in the upper reaches of the Almakashi River include industry and extensive farming activities (Dry and Rainy Seasons). Gwani water receives most of the domestic wastes from Gombe metropolis and the villages along its axis.

No known documented literature exits on biometric indices of *C. gariepinus* and *O. niloticus* of Gongola River corridors in Gombe state exists, therefore the aim of this study was to determine the Biometric Indices of *C. gariepinus* and *O. niloticus* collected from the two sampling area of Almakashi, Gwani in relation to the reference site and the objectives were to examine the condition factor, hepatosomatic indices, gonadosomatic index and splenosomatic index of *C. gariepinus* and *O. niloticus* collected from the sampling locations of Gongola river complex in Gombe State.

MATERIALS AND METHODS

Study Area

The study sites chosen for this research are located within the Gongola River Complex. The Gongola River, situated in northeastern Nigeria, stands as the primary tributary of the Benue River. It originates from the eastern slopes of the Jos Plateau, the Gongola flows into the Gongola Basin, following a northeast trajectory until it reaches Gombe Abba, then Nafada. It takes a southward turn from Nafada, passing through the corridors of the Almakashi landing site and proceeding to the Dadin Kowa Dam, after traversing the Gwani River corridor in the Yamaltu-Deba Local Government of Gombe State (Ighalo *et al*., 2020; Udo, 1970). As it continues its southern course, the Gongola merges with the Dogon Daji River (containing water of the reference location), augmenting its quantity, before ultimately joining the Benue River near the town of Numan.

The Almakashi River proves highly productive, serving as a source of fish meat consumed not only in Bajoga and Kwami Local Government Areas but also in certain parts of Gombe town in Gombe State (URBDA, 2019). It is specifically located in the Bajoga Local Government Area of Gombe State, positioned at longitude 10^{o} 44’ 38.15’’N and latitude 11^{o} 30’ 02.13’’E.

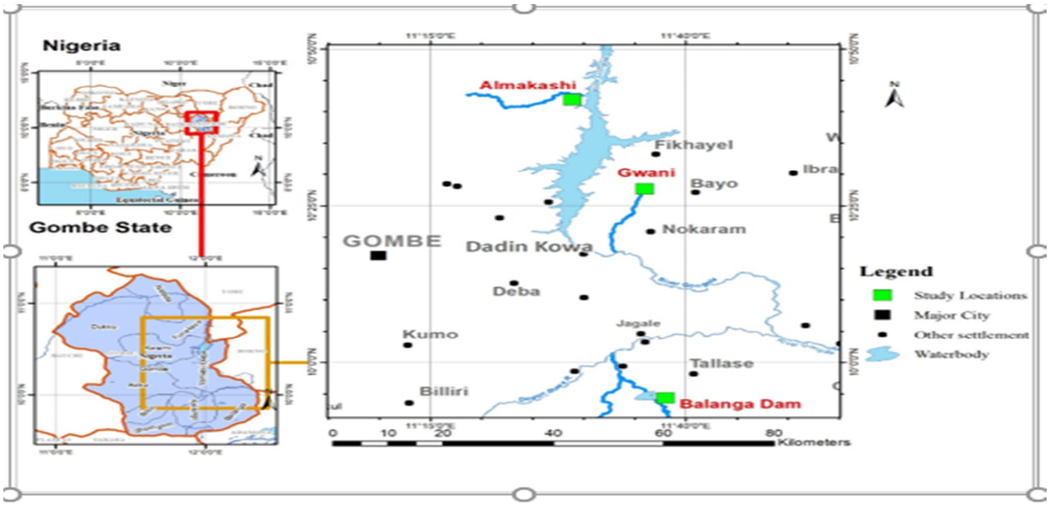

Figure 1: Map of the study area indicating Almakashi, Gwani river catchments of Gongola river complex together with Balanga (the reference dam).

The Gongola River passes through the village of Gwani, dividing it into Gwanin Gabar (eastern Gwani) and Gwanin Yamma (western Gwani), establishing an essential sub-catchment corridor within the Gongola River complex. The residents of Gwani rely directly on the river water for various domestic activities such as drinking, bathing, cooking, and washing clothes. Gwani is positioned between longitude 10 ° 23' 47.035''N and 10 ° 25' 04.89''N, as well as latitude 11 ° 31' 32.013'' and 11 ° 26' 40.24''E.

The reference river of this study is Balanga Dam, situated in the Balanga Local Government Area of Gombe State, is a notable dam characterized by water emerging from beneath the sedimentary rocks. The water flows westward from the dam until it meets River Dogon Daji, ultimately emptying into the lower reaches of the Gongola River, thereby playing a crucial role in replenishing the Gongola River. It is located at longitude 9°35'0" and 10°0'0" N and latitude 11°15'0" and 11°40'0"E.

Biometric Indices

Condition Factor

The Fulton's condition factor (K), which is a relation of length and weight, for each fish was determined using the formula seen below, as quoted by Olapade and Tarawallie (2014).

Condition factor (K) $= \frac{100w}{L^3}$

Where W is the body weight of the fish in grams, and L is the total length of the fish in centimeters.

Hepatosomatic Index (HSI)

The HSI is an organosomatic index which gives an indication of liver weight in relation to total body weight and has been used in stress-related studies. The HSI was determined using the liver weight and total body weight.

$$\text{HSI} = \frac{Liver\ \text{weight}}{Total\ weight} \times 100$$

Sp*lenosomatic Index (SSI)*

The size of the spleen is significant because the spleen functions as a hematopoietic organ. The SSI is a ratio of spleen weight in relation to body weight and is determined using the spleen weight as well as the total body weight.

$$\text{SSI} = \frac{Spleen\ \text{weight}}{Total\ weight} \times 100$$

Gonadosomatic index (GSI)

GSI can give an indication of gonadal development as well as sexual maturity. It is a ratio of gonad weight in relation to total body weight and is determined using the gonad weight as well as the total body weight.

$$GSI = \frac{Gonad\ \text{weight}}{Total\ weight} \times 100$$

Statistical Analysis

The obtained data was analyzed using Statistical Package for the Social Sciences version 22 (SPSS 22) software. Shapiro-wilk test was applied to test the normality of the obtained data. Descriptive statistics was employed to calculate the mean of all the experimental group and the data were presented as mean ± standard deviation (Std dev). This test was utilized to assess whether there was a significant difference between independent and dependent variables in the biometric indices, compared to location, seasons and fish of the sampled fishes. In cases where differences were observed, *Duncan's post hoc* test was conducted to examine the degree of variation. Values of $p < 0.05$ were considered significant.

RESULTS

Biometric Indices

Condition Factor (CF)

The Condition Factor (K) results were consistently within a similar range, showing no significant differences when comparing different groups: Seasons (wet compared to dry; p-value = 0.413), Locations (p-value = 0.054), and Sample species (*O. niloticus* compared to *C. gariepinus*; p-value = 0.945).

The overall well-being of the sampled fish species, measured by the Fulton Condition Factor (K), was analyzed in Almakashi, Gwani, and the reference dam during both dry and wet seasons. *O. niloticus* examined in Almakashi during the dry season exhibited the highest mean CF value of 1.45±2.38, while *O. niloticus* collected during the dry season in Gwani had the lowest value of 0.71±0.54. Regarding location, the Reference River consistently had lower CF values in both dry and wet seasons (CF < 1), whereas all values found in Gwani were > 1, except for *C. gariepinus* examined during the wet season (0.71±0.54). This suggests that fish samples from Gwani were generally in a good healthy stage (CF > 1) (Table **1**).

Hepatosomatic index (HSI)

The Hepatosomatic Index (HSI) values in Almakashi were the highest, with HSI values of 0.98±0.82, while the reference dam had the lowest value of 0.59±0.35 (Table 15). However, these differences were not deemed significant ($p > 0.05$). The mean HSI values across all sampling locations were less than 1 (HSI < 1), indicating insignificant variations (Table **1**).

Gonadosomatic index

O. niloticus from the Gwani river corridor, obtained during the dry season, exhibited the highest Gonadosomatic Index (GSI) value of 2.47±4.04, which was significantly different from the lowest mean values obtained from *C. gariepinus* samples collected in the wet season from the reference dam (0.65±0.22) ($p < 0.05$). However, there was no significant variation between the GSI values of the Almakashi river corridor and that of the reference dam (Table 1). Additionally, a seasonal examination of GSI revealed significant differences between values obtained in the dry season and those obtained in the wet season.

Splenosomatic Index (SSI)

The Splenosomatic Index (SSI) values of 0.05±0.03 found in *O. niloticus* from the reference dam durig the dry season were the lowest mean values compared to the highest values obtained in each of the two river corridors, Almakashi (0.35±0.57 in C. gariepinus during the wet season), and Gwani (0.34±0.49 in C. gariepinus during the dry season), where their values differed significantly from the reference dam ($p < 0.05$) (Table 1).

Therefore, a significant difference exists between the reference river and the two river catchments. On the other hand, there was no significant difference in the mean values of SSI recorded in the dry and wet seasons (p > 0.05). In this study, all the somatic values obtained were in multiples of 10^-3 (×1/1000).

Table 1: Biometric Indices of Sampling Fishes Measured in Dry and Wet Season

Location	Fish	Season	CF	HIS	GSI	SSI
Almakashi	*C.gariepinus*	Dry	1.41±1.77[a]	0.98±0.82[a]	0.78±0.78[c]	0.28±0.45[a]
Almakashi	*C.gariepinus*	Wet	0.90±0.93[b]	0.97±0.93[a]	0.93±0.97[b]	0.35±0.57[a]
Almakashi	*O. niloticus*	Dry	1.45±2.38a	0.81±0.83[a]	0.79±0.60[c]	0.19±0.24[b]
Almakashi	*O. niloticus*	Wet	0.87±0.76[b]	0.90±0.76[a]	0.98±1.04[b]	0.25±0.43[b]
Gwani	*C. gariepinus*	Dry	1.06±1.20[a]	0.90±0.79[a]	1.05±1.74[b]	0.34±0.49[a]
Gwani	*C.gariepinus*	Wet	0.71±0.54[b]	0.88±0.60[a]	0.78±0.72[c]	0.28±0.33[a]
Gwani	*O. niloticus*	Dry	1.09±0.64[a]	0.80±0.48[b]	2.47±4.04[a]	0.23±0.35[b]
Gwani	*O. niloticus*	Wet	1.12±0.59[a]	0.82±0.83[b]	0.98±1.03[b]	0.17±0.15[b]
Reference	*C.gariepinus*	Dry	0.73±0.21[b]	0.66±0.33[b]	0.78±0.37[c]	0.07±0.12[c]
Reference	*C.gariepinus*	Wet	0.74±0.36[b]	0.59±0.35[b]	0.65±0.22[c]	0.09±0.15[c]
Reference	*O. niloticus*	Dry	0.86±0.53[b]	0.66±0.29[b]	0.70±0.29[c]	0.05±0.03[c]
Reference	*O. niloticus*	Wet	0.94±0.54[b]	0.81±0.33[a]	0.71±0.31[c]	0.08±0.06[c]
Location			0.054	0.028*	0.0035*	0.000*
Fish			0.945	0.645	0.070	0.04*
Season			0.413	0.41	0.264	0.992
Season*Fish			0.495	0.993	0.264	0.864
Location*Fish			0.515	0.398	0.042*	0.502
Season*Location*Fish			0.75	0.864	0.121	0.992

Keywords: CF= Condition Factor; **HSI= hepatosomatic Index; GSI= Gonadosomatic Index, SSI=Splenosomatic index.** [ab]= significant difference (p value = 0.05); [aa] = insignificant. Same superscript in the same column indicates no significant difference while a different value at the same column shows significant difference.

DISCUSSION

Biometric Indices

Condition Factor, Hepatosomatic Index, Spleen index and Gonadosomatic Index are essential biometric indices used in fisheries biology to evaluate the health, liver condition, spleen condition and reproductive status of fish populations, providing valuable insights into their overall condition and well-being.

Condition Factor (K)

The Condition Factor (K) is a measure of the overall well-being and health of a fish. The Condition Factor is influenced by various environmental factors and provides insights into the general health and robustness of fish populations (Dambo *et al.*, 2021; Olapade and Tarawallie, 2014). Condition factor of fish has been widely used in the assessment fish health and population study. In this present study, Fulton‘s condition factor was employed. This factor can be indicative of the overall condition and nutritional status of an individual fish (Uka and Sikoki, 2024). Previous study on length-weight data attested that the heavier the fish the better condition it will be (Bolger and Connolly 1989).

Fish weight is affected by many factors including food availability, metabolic rate as dependant on temperature and seasonal changes in terms of breeding activity (Smith, 2023) and may increase or decrease in response to chemical contaminants (Schmitt and Dethloff, 2000). Because fish condition factors vary between species due to their differing architecture. In this study, the CF of the two species was compared with respect to locations and season. *O. niloticus* examined in Almakashi during dry season had the highest mean CF value of 1.45±2.38 (Table 1).

The highest mean Cf value from Almakashi site in dry season may be attributed to the effect of seasonality. The higher Cf results could be because the fish are in their breeding periods and thus their body mass is increased as a result of increased gonad mass; these results are reflected in the GSI values (Table 15). Generally, *O. niloticus* had higher mean CF values compared to *C. gariepinus*. This is in line with the findings of Van Dyk (2006) who recorded a mean Cf value of 1.64 in *Oreochromis mossambicus* which has a more rounded body shape and a mean Cf value of 0.67 in *Clarias gariepinus*, which is a long, dorso-ventrally flattened fish, suggesting that body shape plays a vital role in determining Cf values. Another study that supports this suggestion was the similar study conducted by Van Dyk *et al.* (2009b) in the Okavango panhandle, recorded higher values of Cf of 1.8 and 1.6 in *Oreochromis andersonii* and *Seranochromis angusticeps* respectively while 0.8 and 0.7 were the mean CF values recorded in *Clarias gariepinus*, and *Clarias ngamensis*, respectively.

The CF values in wet seasons from all the sampling locations were less than the CF mean concentration observed in dry season. This is similar to the findings of Smiths *et al*., (2012) who obtained CF value <1 in rainy season in *Labeo marequensis* and *Labeo rosae* collected from the Olifants river in South Africa. The lower CF value in wet season observed in this study indicated that both *O. niloticus* and *C. gariepinus* are not in a very good condition which may be due to the fact that the fish samples were caught during a period of heavy rains which may have cause the fish to stress (Abujanra *et al*., 2009). In general, there was no significant difference of CF between the sampling species across the two main seasons in all the sampling locations.

The lowest mean concentration observed in both dry and wet season found in the reference river was a surprised because the reference river had less human activities but still had less CF mean values that are less than one (<1), this may be attributed to the over exploitation of the large size fish species of *C. gariepinus* and *O. niloticus* because of the high clarity of the water that often exposed them to predators and artisanal fishermen.

Hepatosomatic Index (HSI)

The HSI otherwise known as liver index (HSI) is a useful biomarker that is commonly used to detect the risk effects of environmental stressors (Narra, 2016). Liver is the major detoxification organ in fish, in this process, it may become affected which could lead to a decreased in HSI (Narra *et al*., 2017). The mean HSI values in all the sampling locations of this study indicate insignificant differences ($p > 0.05$) (Table 15). The hepatosomatic index (HSI) is a ratio of liver weight to body weight and can be altered by contaminant exposure (Schmitt and Dethloff, 2000). The normal value for HSI ranges from 1-2% for bony fishes (Munshi and Dutta, 1996), even though the range is species specific. Van Dyk, (2006) provided a baseline information of HSI in a laboratory-based study of two important South African fish specimens namely *Clarias gariepinus* and *Oreochromis mossambicus* in which the mean Hepatosomatic index values of *C. gariepinus* and *O. mossambicus* were 1.08% and 1.30% respectively.

Conversely, the range of HSI values obtained in Almakashi, Gwani and the reference dam were 0.98±0.82% in *C. gariepinus* obtained in dry season at Almakashi to 0.59±0.35% found in *O. niloticus* samples collected in wet season at the reference location; all the values were <1% (Table 15).

The HSI values of these specimens from all the study areas were all below the supposedly normal as explained above. This is similar to the HSI values reported by Van Dyk *et al.* (2009a) in Okavango panhandle and revealed the HSI values of <= 1 for all the four examined fish specimens thus, *Clarias gariepinus* had 0.50%; *Clarias ngamensis* had 0.60%; *Oreochromis andersonii* had 1.00%; and *Serranochromis angusticeps* had 0.80%. The lower-than-expected HSI values may be attributed to the fact that the fish specimens were under stress and the same may be true of the fish specimens examined by Smith (2012). There is an inverse relationship between body condition and amount of rainfall (wet conditions) (Abujanra *et al.*, 2009) and it is likely that the high amount of rainfall during the wet season in all the sampling locations which may have stressed both the *O. niloticus* and *C. gariepinus* and caused them to have lesser HSI values. On a contrary way, Figueiredo-Fernandes *et al.* (2007) reported higher values of *O. niloticus* exposed to copper condition.

Gonadosomatic Index (GSI)

The gonadosomatic index (GSI) is an indicator of the maturity of the gonads and its development. This has been found useful in assessing gonadal alterations in response to seasonal dynamics and contaminant stresses (Schmitt and Dethloff, 2000). The highest GSI mean concentration of 1.05±1.74% and 2.47±4.04% in both *C. gariepinus* and *O. niloticus* were respectively found in dry season at Gwani sampling locations. It is possible that the significant increase in GSI in Gwani sampling site and the reference dam) was most probably due to seasonality (Smith, 2012), as the higher GSI results were found closer to the summer breeding season of the fish sampled. The highest mean GSI value found in dry season at Gwani sampling location (Table 15) may be attributed to the breeding periods of the sampling fish species and thus their body weight is elevated due to an increased gonad weight (Roy *et al.*, 2014).

Splenosomatic Index

The splenosomatic index (SSI) is a ratio of the weight of spleen per weight. Measuring SSI is very essential because spleen is a haematopoietic organ and therefore plays vital role in the immune system (Schmitt and Dethloff, 2000) thus, any alteration of the spleen is considered to be symptomatic of disease (Goede and Barton, 1990). The highest mean concentration of SSI was 0.35±0.57% found in *C. gariepinus* at Almakashi in wet season while the lowest mean concentration was 0.05±0.03% found in *O. niloticus* samples collected in wet season from the reference river. Therefore, there exists a significant increase in the mean values obtained in the reference river in comparison to the two river catchments ($p < 0.05$) (Table 15). Moreover, The SSI mean values of *O. niloticus* and *C. gariepinus* varied significantly and were higher than values obtained by Van Dyke, (2006). This study recorded low values of 0.05±0.03% (0.05%) and 0.07±0.12% (0.07%) in *O. niloticus* and *C. gariepinus* at the reference river. SSI values from a Southern African laboratory-based baseline study showed SSI values of 0.04% in *C. gariepinus* specimens and 0.06% in *O. mossambicus* specimens (Van Dyk, 2006) and the SSI results of this study differed from their findings despite the fact that the values varied slightly with that of the reference dam. Variations in the morphology of spleen between species may be responsible for the low values of SSI (Schmitt and Dethloff, 2000).

CONCLUSION

The stress condition in Gongola river corridors analysed in this research alters some biometric indices. However, the alteration is reversal when the stress condition is subsides. Therefore, there is need to apply for a more composite and most prevalent indices such as Health Assessment Index (HAI) that can integrate multiple measures related to body condition in the future research.

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