LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR OF AFRICAN MUD CATFISH (*Clarias gariepinus)* and TILAPIA (*Tilapia niloticus)* IN ORASHI RIVER OF OGBA/EGBEMA/NDONI LGA OF RIVERS STATE, NIGERIA.

Comment [A1]: Accepted name: *Oreochromis niloticus* (Linnaeus, 1758). Please change in all paper

ABSTRACT

Length-weight relationship (LWR) and condition factor are important in fishery assessment studies since it provide information about the growth of the fish, its general wellbeing and fitness in aquatic habitat. LWRs for 2 fish species – *Clarias gariepinus* and *Tilapia niloticus* collected from Orashi River were established and their growth condition was evaluated. The study was carried out from September 2019 to August 2020. The biometric measurement (length/weight) shows that the weight of the fish increased in proportion to its length as indicated by the slope (b) of the relationship. The mean value shows strong relationship because coefficient of determination (R^2) is >0.5 and range from 0.795-0.985. Higher values of both length and weight were recorded for Catfish over Tilapia. The results indicated that almost all the fish sampled exhibited a positive allometric growth and trended to grow bigger. All relationship were statistically significant (p=0.05). The mean Fulton's condition factor (K) of the fish range from Catfish (1.24-1.80) and Tilapia (1.5-3.7) in the 5 stations sampled. The result showed that Tilapia had a high mean range and therefore was in better conditions than the Catfish. This gives information on the food supply, timing and duration of breeding cycle. The indices may also be used in the general assessment of the "well being" of a fish (Nwadiaro and Okorie 1985). Multiple comparison tests using Turkey Kramer showed that the condition factor of Catfish from Okwuzi ~~(station 1)~~ was significantly different from that of Ndoni and Omoku but Ebocha and Obrikom was not significantly different from each other. With regards to seasonal variation, **dry season** recorded higher values than **rainy season.**

Formatted: Highlight

Keywords: biometrics, regression coefficient, growth, Orashi river

INTRODUCTION

Fish plays a vital role in feeding the world's population and contributing significantly to the dietary protein intake of hundreds of millions of the populace. Unfortunately, fish stock are depleting worldwide notably in the study areas mainly because of over-exploitation and environmental degradation caused, among other things, by pollution (Asonye *et al,* 2007; Okwodu, 2016). Fisheries management addresses among others, the economic, social and biological factor affecting fish stock in order to adopt a strategy that fulfills the feeding requirements of societies without exploiting fish stocks (FAO, 1983, Okwodu, 2016). In biometric studies, it is imperative to determine the growth characteristics related to the weight and length of the fish, in addition to the condition of wellbeing of the species influenced by different biological and environment factors (Nwadiaro *et al*, 1985, Lizama *et al,* 2010). The importance of determining length-weight relationships (LWRs) in fish has been emphasized by many studies. It provides information about the growth pattern, general health, habitat conditions, life history, fish fatness and condition, as well as morphological characteristics of the fish (Froese, 2006).

Fish Length-Weight Relationship (LWR) is of great importance in fishery assessments, converting length observations into estimates to provide some measure of biomass (Froese 2006). Length-weight regression has been used frequently to estimate weight from length because direct weight measurements can be time consuming in the field. Knowledge of length-weight relationship and population dynamics of the fish are vital in fishery science (Lizama *et al,* 2010). Additionally, the LWR is useful for comparing the life history of a species in different regions and/or seasons.

In fish, condition factor (K) reflects through its variations and provides information on the physiological state of the fish in relation to its welfare and based on the hypothesis that heavier fish of a given length are in better condition (Nwadiaro *et al*, 1985). The condition factor is usually influenced by age of the fish, sex, season, maturity stage etc. Furthermore, length-weight regressions have been used extensively for conversion of growth in length equations to growth in weight equations in the stock assessment model; for estimation of standing crop biomass when the length frequency distribution is known, and for predicting the condition index.

The current study provided the first baseline data about LWRs and relative condition factor of fish species from the Orashi River of Rivers State, Nigeria. Such data is valuable for establishing a monitoring and management system of these and other fish species.

Water is the most important natural resources and there are many conflicting demand for them. Skillful management of water bodies is required if they are to be used for such diverse purpose as domestic and industrial supply, crop irrigation, transport, recreation, sports, commercial fisheries, power generation and waste disposal.

Fishes are dependent on the water as a medium in which to live. All vital metabolic functions of fish such as respiration, feeding, movement, growth and reproduction are all dependent on water. Water is therefore the high way, byway, communication medium, nursery, play ground, school, room, bed, drink, toilet and grave for a fish.

Water bodies are vulnerable to contamination accident and bioterrorism attacks because they are relatively unprotected, easily accessible, often isolated and their various use by human pre-disposes them to contamination. (Gullick *et al*; 2003). Environmental exposure to toxic metals is a critical issue in environmental and public health.

There are several human activities which have indirect and undesirable, if not devastating effects on the aquatic environment and its components.

The Orashi river is a non-tidal freshwater of the lower Niger basin that runs through some communities in Imo State, Ogba/Egbema/Ndoni LGA (ONELGA) in Rivers State and empties in Sambreiro River in Ahoada. The natural aquatic habitat of Orashi River of ONELGA may have changed as a result of the intense industrial activities - oil exploration and exploitation, bunkering activities and oil pipeline vandalization, clearing of bank vegetations, annual dredging of the river to contain flooding, construction of roads and bridges, drains and embankment walls and the river provides habitat for many plants and aquatic species including fishes.

It is therefore imperative to conduct this study to determine the health status and biomass of the aquatic life (Flora and fauna) in relation to the suitability of the water and the level of pollution of the Orashi River for sustaining aquatic life and in comparison to establish standards.

Comment [A2]: Is there any information on the life cycle of the two species? When do they reproduce?

The data generated will serve as baseline information for subsequent monitoring studies and for management of the fishery and the environment since no systematic study has so far been conducted in Orashi River of ONELGA to ascertain its level of contamination, health effects on biota and the inhabitants. This may be attributed but not limited to the 'restive nature' of the inhabitants of the area as researchers may be vulnerable to attack by the youths who always vent their anger on soft targets.

AIM: Investigation of the health status of fishes in relation to the level of pollution of Orashi River using length-weight relationships

OBJECTIVES: The specific objectives of this study are:

1. To estimate LWRs for two fishes (*Clarias gariepinus* and *Tilapia niloticus*). This is to assess their growth pattern, general health, habitat conditions, life history, fish fatness and condition, as well as morphological characteristics of the fish
2. To assess the condition factor (K) and evaluate the fitness of the water body for fish growth and survival.
3. To assess the seasonal variations in the growth of the 2 species from Orashi River by comparing their morphological characteristics.

Formatted: Highlight

MATERIALS AND METHODS

THE STUDY AREA

The study area is Ogba/Egbema/Ndoni LGA in Rivers State of Nigeria. (Fig: 1a, b & c). The area hosts two oil companies - Nigerian Agip Oil Company (NAOC) and Total E & P Nigeria Limited exploring and exploiting crude oil as well as flaring gases indiscriminately in the area. The inhabitants of the area are predominantly farmers and fishermen which is their basic source of livelihood. The area has a growing population of 283, 294 in 2006 and a projection of 398,000 in 2016 (National population commission of Nigeria (web), National Bureau of statistics (web).

The site is Orashi river, a non-tidal freshwater of the lower Niger basin that runs through some communities in Imo State, Egbema, Ndoni, and Ogba communities in Rivers State and empties into Sombreiro river in Ahoada LGA. (Plate 1).

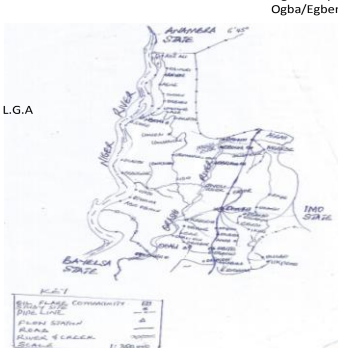
The area is tropical with two seasons- the rainy (April – September) and dry season (October – March) which are usually flooded in the rainy seasons.

Fig 1: maps showing the study area

Fig 1a. Map of Nigeria Showing Rivers State

Fig.1b Map of Rivers State Showing Ogba/Egbema/Ndoni L.G.A

Fig.1c Map of Ogba/Egbema/Ndoni L.G.A



Maps should be improved and sampling stations should be represented

Plate 1: Containment of Oil spill in Orashi River along station 2 during the study period.

SAMPLING STATIONS

A reconnaissance survey was carried out in the study area on March, 2019 and then sampling stations were established at five locations along the Orashi River, 5km distance from each other using Global positioning system navigator (GPS) as shown in Table 1 and represented by station 1 – 5.

Table 1: Geographical positioning system (GPS) -GPS-Grami 785

STATIONS	LOCATIONS	COORDINATES	ELEVATION

Station 1	Okwuzi	N05^{0}29’08.3” E006^{0}42’26.3”	21m
Station 2	Ebocha	N05^{0}27’49.3” E006^{0}42’06.6”	24m
Station 3	Ndoni	N05^{0}27’24.6” E006^{0}40’27.8”	12m
Station 4	Obrikom	N05^{0}23’31.0” E006^{0}39’03.0”	22m
Station 5	Omoku	N05^{0}20’18.7” E006^{0}38’34.6”	16m

COLLECTION AND ANALYSIS OF FISH SAMPLES

The fish samples - Catfish (*Clarias gariepinus*) and Tilapia (*Tilapia niloticus*) were purchased from artisanal fishermen monthly from September 2019 to August 2020 landing at each station fishing ports. They are kept alive and intact for direct biometric measurement from the five (5) stations for each sampling period. The samples were transferred to the Institute of Pollution Studies (IPS) laboratory of the Rivers state university. They are washed in distilled water, photographed and identified down to the species by the fishery scientist of IPS - Prof. E.R Daka (Director, Institute of pollution studies, Rivers State University) using taxonomic keys (Idodo-Umeh, 2003). Length measurements were recorded as total length (TL in cm) from the mouth to the end of the caudal fin measured to the nearest 0.1cm by using regular ruler. Weight was measured using a digital balance with an accuracy of 0.01g.

Comment [A3]: Previously, it was mentioned that a reconnaissance of the area was carried out to define the location of the sampling stations. Here they mention that the fish was bought from the fishermen. Did the authors accompany the fishermen in the sampling or what kind of agreement was made with them regarding the fishing location?

Plates 2: *Tilapia niloticus*   Plate 3: *Clarias gariepinus*

Formatted: Highlight

DATA ANALYSIS

All statistical analysis and presentation of results was done using Microsoft excel and Minitab 16 software (references).

Regression analysis was done to compare the length/weight relationship to establish the condition factor of the fishes from Orashi River.

Pearson product moment correlation using EXCEL was done to establish relationship between pairs of variables.

For computation of the condition factor of fish species, Fulton's condition factor (K) was calculated by Htun-Han (1978) equation as per formula given as: $K = \frac{W\ X\ 100}{L3}$ Where W = weight of fish (g), L =Length of fish (cm)

Comment [A4]: the authors should describe how they analyse allometric growth described in results section

Analysis of variance (single factor) was used to test for significant differences between the condition factors values of Catfish and Tilapia from the five study locations.

Mean separation was done using Turkey-Kramer test.

RESULTS

(1) LENGTH - WEIGHT (L-W) RELATIONSHIP OF CATFISH AND TILAPIA

The length-weight relationship shows the rate of growth in length as well as increase in size (biomass). The biometric measurements of the two fish were taken, regression equation given and regression graph plotted according to data obtained on monthly sampling. The graph is presented in fig 2 to 25 below with the following results:

Comment [A5]: is not a growth rate. Maybe write "weight increase with length increase"

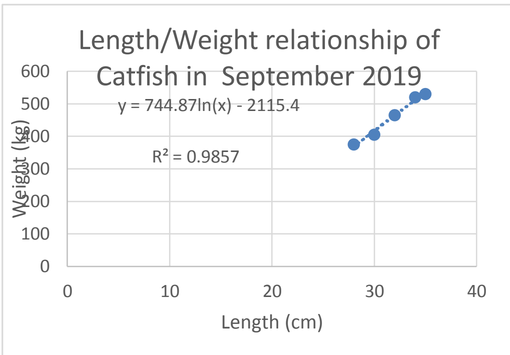
(i) Higher values of both length and weight were recorded for Catfish over Tilapia in all samples.

(ii) Almost all the fish sampled exhibit a positive allometric growth except Tilapia sampled in October 2019.

(iii) From the graph: R^2 = Coefficient of determination expresses the relationship between the length and weight of the fish. The range of coefficient of correlation (r) ranged from 0.795 - 0.985

(iv) The weight of the fish increased in proportion to its length as indicated by the slope (b) of the relationship in all the graphs. In all, the mean value shows strong relationship as R^2 is greater than 0.5 and less than or equal to 1. ($R^2 > 0.5 \leq 1$).

(v) All relationships were statistically significant ($p < 0.05$)



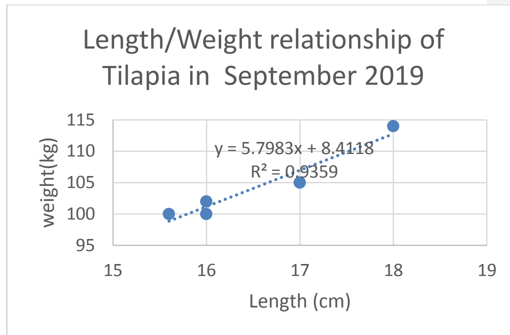
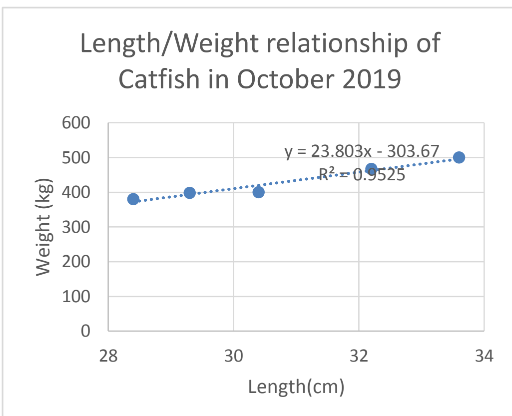


Fig 2: L-W Relationship of Catfish

Fig 3: L-W Relationship of Tilapia

Comment [A6]: Change the graphics: delete title and put the necessary information in the legend. The units on the Y-axis should be corrected to grams, or even better consider replacing all these graphs with a table that would include the regression equation, values of a, b, R2 and the N.



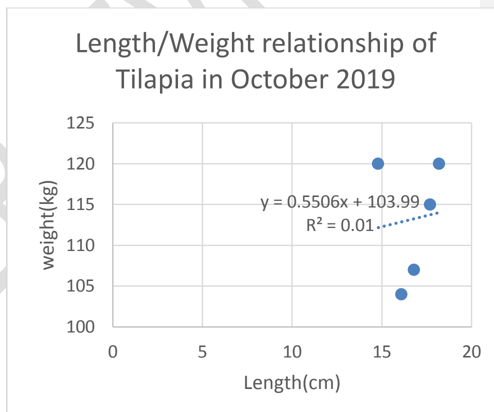


Fig 4: L-W Relationship of Catfish

Fig 5: L-W Relationship of Tilapia

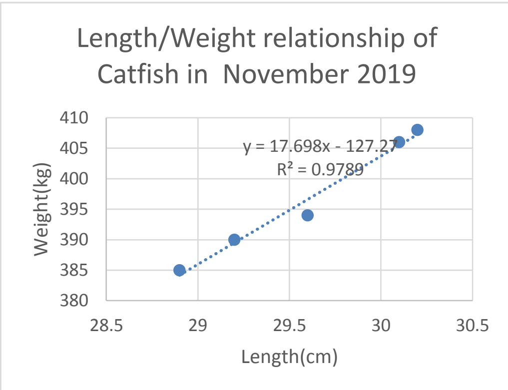


Fig 6: L-W Relationship of Catfish

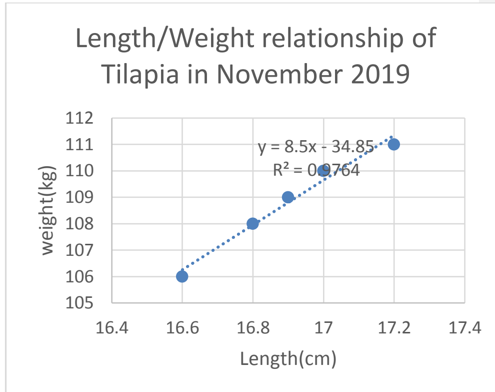


Fig 7: W-L Relationship of Tilapia

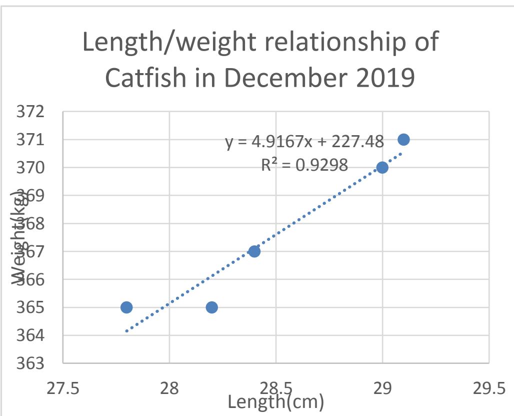


Fig 8: L-W Relationship of Catfish

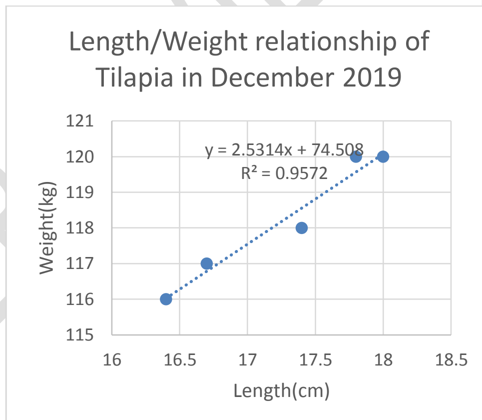


Fig 9: L-W Relationship of Tilapia

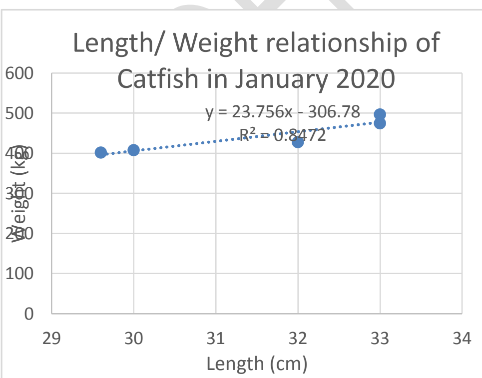


Fig 11: L-W Relationship of Tilapia

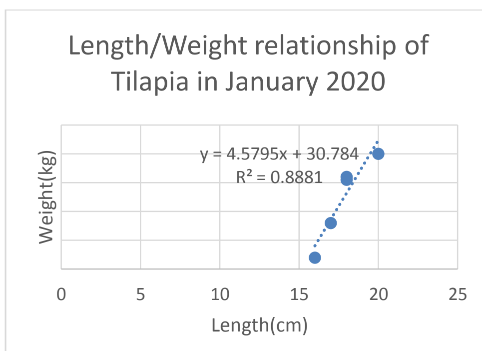


Fig 10: L-W Relationship of Catfish

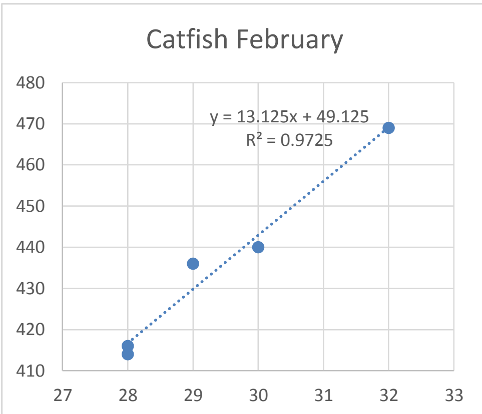


Fig 12: L-W Relationship of Catfish

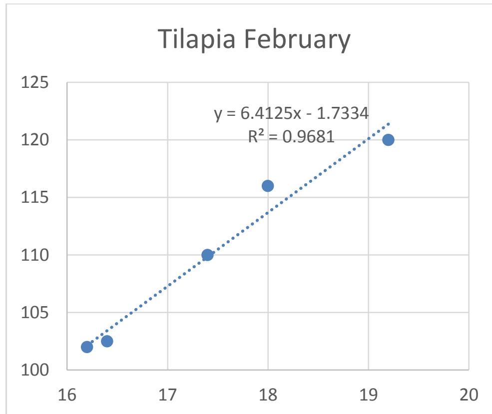


Fig 13: L-W Relationship of Tilapia

Comment [A7]: Several figures without units on the axes

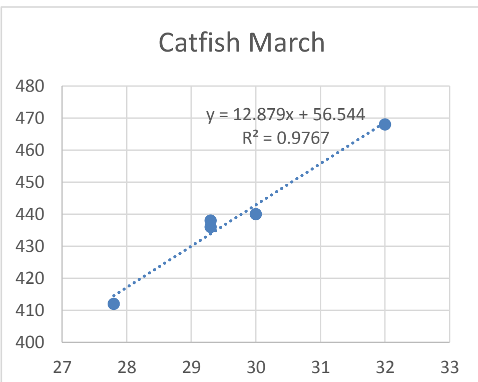


Fig 14: L-W Relationship of Catfish

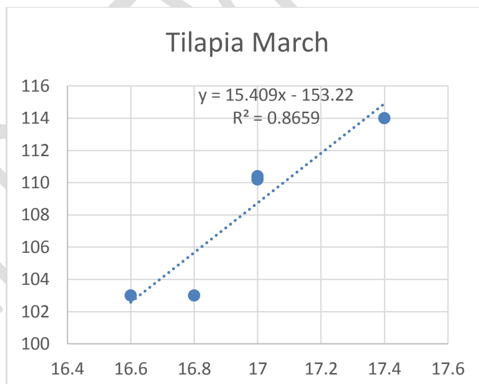


Fig 15: L-W Relationship of Tilapia

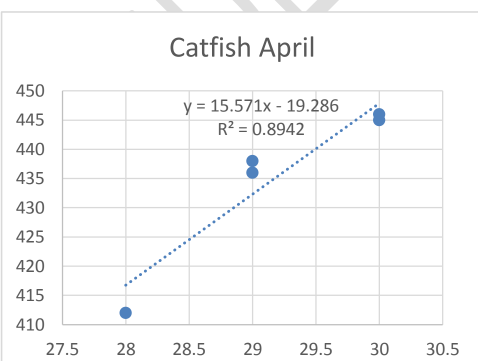


Fig 16: L-W Relationship of Catfish

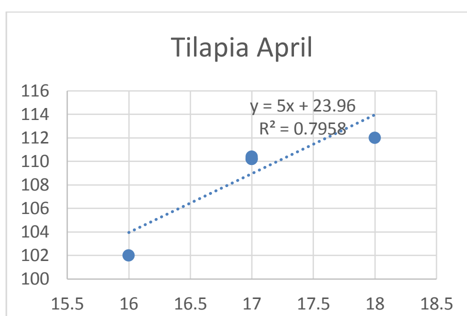


Fig 17: L-W Relationship of Tilapia

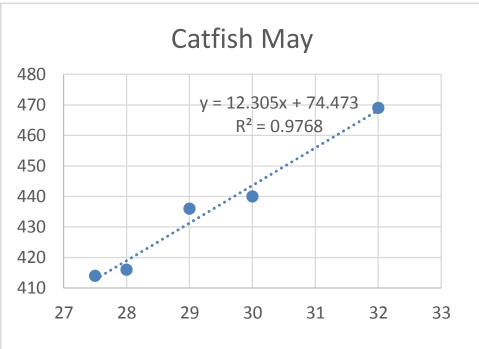


Fig 18: L-W Relationship of Catfish

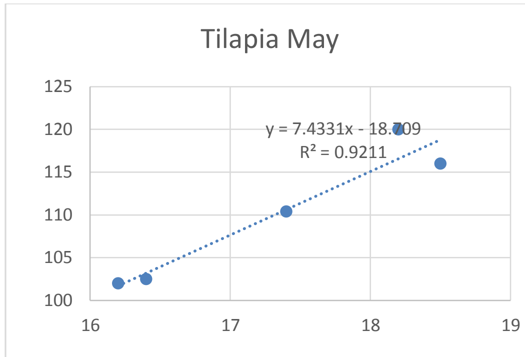
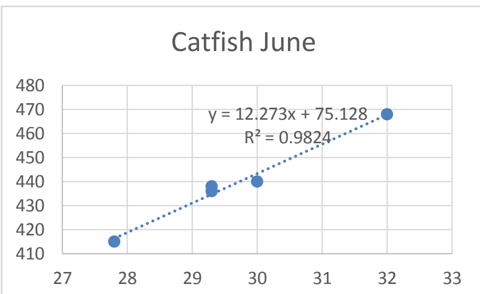


Fig 19: L-W Relationship of Tilapia



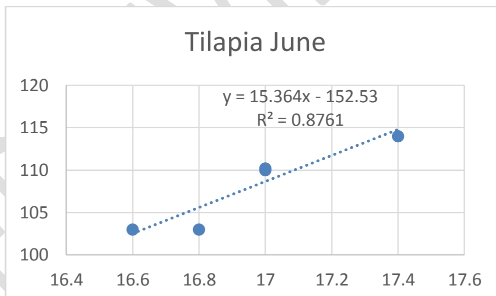


Fig 20: L-W Relationship of Catfish

Fig 21: L-W Relationship of Tilapia

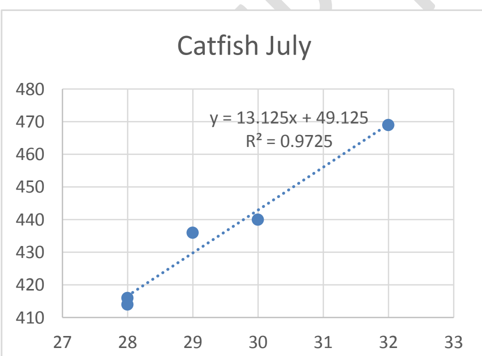


Fig 22: L-W Relationship of Catfish

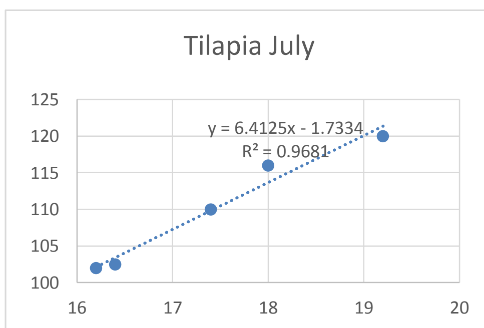


Fig 23: L-W Relationship of Tilapia

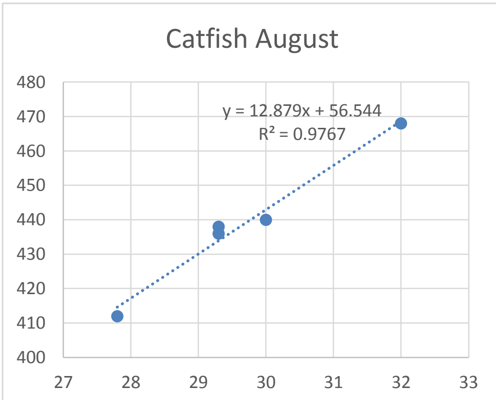


Fig 24: L-W Relationship of Catfish

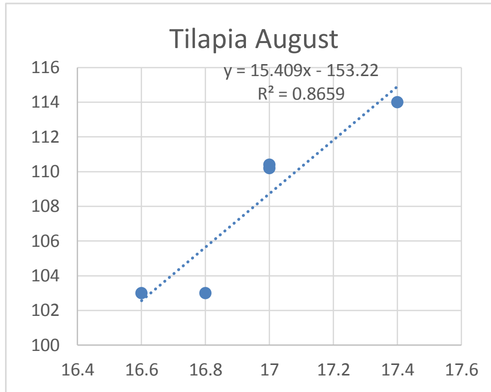


Fig 25: L-W Relationship of Tilapia

(2) CONDITION FACTOR

Condition factor values for all fish specimens were above 1.00 (Table 2). With regard to Catfish, the ranges of the condition factor from the study locations were Station1 (1.48-1.99), Station 2 (1.31-1.79), Station 3 (1.32-1.65), Station 4 (1.42-1.90) and Station 5 (1.24-1.80). It was observed that mean condition factor values were similar. Mean K=1.54 for Catfish from stations 3 (Ndoni) and station 5(Omoku); mean K was 1.6 at station 4(Obrikom), 1.65 at station 2(Ebocha) and 1.77 at station 1(Okwuzi).

Comment [A8]: Add standard deviation on mean K value

Mean K was of the pattern **Okwuzi > Ebocha > Obrikom > Ndoni > Omoku.** Values for Tilapia were higher than that of Catfish from all stations throughout the study period. Condition factor ranged from station 1(1.99-2.49), station 2(2.00-2.49), station 3(1.5-3.7), station 4(2.07-2.63) and station 5(1.83-2.5). Mean condition factor for Tilapia was 2.13 at Omoku, 2.18 at Ebocha and Ndoni, 2.3 at Okwuzi and 2.31 at Obrikom.

Comment [A9]: Add standard deviation

The pattern was **Obrikom > Okwuzi > Ndoni > Ebocha > Omoku.**

Although the condition factor of all fish samples examined in this research were above 1, it was observed that the lowest mean K values (1.54 for Catfish and 2.13 for Tilapia) were obtained in fish samples from Omoku.

Analysis of variance showed that for Catfish, there were **significant differences** (p = 0.011) in the condition factor. Multiple comparison tests using Tukey Kramer showed that the condition factor of Catfish from Okwuzi was **significantly different** from that of Ndoni and Omoku, but Ebocha and Obrikom was **not significantly different** from each other and from Ndoni and Omoku. As such, the condition factor of Catfish at Okwuzi was **significantly higher** than that from Ndoni and Omoku (Table 3).

Analysis of variance for condition factor values of Tilapia from the 5 study locations showed there was **no significant difference** (p = 0.452) (Table 4).

Table 2: Range and mean values of the weight, total length and condition factor of Catfish and Tilapia specimen from five study locations (Sept, 2019 – August, 2020).

Comment [A10]: In the table add the number of individuals of each species, at each sampling station

STATION 1: OKWUZI				
	CATFISH		**TILAPIA**	
	RANGE	**MEAN**	**RANGE**	**MEAN**
W (G)	365-415	404.92± 15.76	100-120	107.53±7.05
TL (cm)	27.5-30.2	28.44±1.00	16-18.2	16.73±0.77
K	1.48-1.99	1.77±0.19	1.99-2.49	2.30±0.16
STATION 2: EBOCHA				
	CATFISH		**TILAPIA**	
	RANGE	**MEAN**	**RANGE**	**MEAN**
W (g)	370-467	422.33±29.2	103-118	108.4±5.06
TL (cm)	28-32.2	29.53±1.25	16.1-18	17.08±0.48
K	1.31-1.79	1.65±0.16	2-2.49	2.18±0.12
STATION 3: NDONI				
	CATFISH		**TILAPIA**	
	RANGE	**MEAN**	**RANGE**	**MEAN**
W (g)	367-520	445.08±40.88	100-120	114.5±6.48
TL (cm)	28.4-34	30.72±1.77	14.8-20	17.58±1.49
K	1.32-1.65	1.54±0.14	1.5-3.7	2.18±0.57
STATION 4: OBRIKOM				
	CATFISH		**TILAPIA**	
	RANGE	**MEAN**	**RANGE**	**MEAN**
W (g)	365-468	426.25±35.89	102-116	106.14±5.06
TL (cm)	28-32	29.93±1.72	16-17.7	16.64±0.43
K	1.42-1.9	1.60±0.20	2.07-2.63	2.31±0.14

	STATION 5: OMOKU			
	CATFISH		**TILAPIA**	
	RANGE	**MEAN**	**RANGE**	**MEAN**
W(g)	371-530	446.25±43.83	107-117	113.56±3.15
TL (cm)	29-35	30.78±1.96	16.7-18.5	17.51±0.56
K	1.24-1.8	1.54±0.17	1.83-2.51	2.13±0.18

W =wet body weight; TL = total length; ±=standard deviation

Table 3: One-way ANOVA: Condition Factor values of Catfish between Locations

Source	DF	SS	MS	F	P
Factor	4	0.4395	0.1099	3.61	0.011
Error	55	1.6723	0.0304		
Total	59	2.1118			

Grouping Information Using Tukey Method

STATIONS	N	MEAN	GROUPING
Okwuzi	12	1.7717	A
Ebocha	12	1.6508	A
Obrikom	12	1.6033	A
Ndoni	12	1.5425	B
Omoku	12	1.5400	B

N/B: Means that do not share a letter are significantly different.

Table 4: One-way ANOVA: Condition factors of Tilapia between locations

Source	DF	SS	MS	F	P
Factor	4	0.3119	0.0780	0.93	0.452
Error	55	4.5993	0.0836		
Total	59	4.9112			

Grouping Information Using Turkey Method

STATIONS	N	MEAN	GROUPING
Okwuzi	12	2.3050	A
Ebocha	12	2.3042	A
Obrikom	12	2.1825	A
Ndoni	12	2.1825	A
Omoku	12	2.1258	A

DISCUSSION

Comment [A11]: The authors should discuss Length-weight relationship and questions associated, like number of individuals sampled, absence of juveniles in the sample, sex-ratio and so on...

Condition Factor

The condition factor is used as an indicator of the health status of fishes (Froese, 2006, Nwadiaro and Okorie 1985) and can be used to compare the condition of fish species exposed to different environmental conditions and feeding regimes (Lizama *et al*., 2002).

It is generally accepted that a condition factor of 1 and above indicates good health in fishes (Jisr *et al*., 2018) and it decreases with increase in length suggesting that the heavier fish at a given length is healthier (Bolger and Connolly, 1989; Abowei and Davies, 2009).

The condition factor of all samples of Catfish and Tilapia examined in the course of this research was greater than 1. Considering the fish samples together irrespective of location, the ranges of K obtained in this present research were 1.24-1.99 for Catfish and 1.5-3.7 for Tilapia. This indicates that the fish were in good condition (Chukwu and Dekae, 2010).

In a research by Abu and Agarin (2016), the condition factor of the Silver Catfish (*Chrysichthys nigrodigitatus*) caught from the Choba axis of the New Calabar River ranged between 0.85 and 1.98, with a mean of 1.34. Though the highest value these authors obtained (K=1.98) is close to the highest K value (1.99) obtained for Catfish in this present study, they had values of K below 1 and the mean K they computed was also lower than the mean K for Catfish from the five study locations of this study: 1.7, 1.65, 1.54, 1.6 and 1.54 for Okwuzi, Ebocha, Ndoni, Obrikom and Omoku respectively.

In another research, Ayo-Olalusi (2014) computed mean K of 0.7987 for *Clarias gariepinus* reared in flow-through system tanks. Ndome *et al*. (2012), in their own study, reported on the condition factor of the smooth-mouth marine Catfish (*Clarias heudelotii*) harvested from Ibeno Local Government Area of Akwa Ibom State, Nigeria.

These authors computed a condition factor of 1.29. Though this value was greater than one, it was less than the mean K computed for Catfish in this present study. This shows that irrespective of the anthropogenic activities going on at Okwuzi, Ebocha, Ndoni, Obrikom and Omoku, the waters provide nourishment for Catfish and Tilapia species.

The condition factor of Tilapia species recorded in the present research (1.5-3.7) is quite high as compared to reports by several other authors. The mean K values were Station 1(2.30), Station 2(2.18), Station 3(2.1), Station 4(2.31) and Station 5(2.13). Igwela *et al*, (2011) reported condition values ranging from 1.64 to 1.79 in *Oreochromis niloticus* fingerlings fed on different levels of maltose. Nehemiah *et al*, (2012) reported on the condition factor of *Tilapia zillii* and *Oreochromis urolepis urolepis* reared in full strength sea water and in fresh water. These authors found that *T. zilli* had K value of 2.07 and 0.74 in freshwater and sea water, respectively. *Oreochromis urolepis urolepis,* on the other hand, had K 0.86 and 0.53 in fresh water and sea water respectively, thereby indicating that salinity and species could affect the condition factor of

Tilapia. Shahabuddin *et al*, (2015) reported K of 1.2 -1.7 in *Oreochromis niloticus* fed with protein diets. However, Obasohan *et al*, (2012) reported high values for *Tilapia mariae* and *Oreochromis niloticus* harvested from Ibiekuma stream in Ekpoma, Edo State, Nigeria. The values of K were 3.78 in *T. mariae* and 3.26 in *O. niloticus*. Therefore, fish species are able to attain high levels of condition factor depending on the factors prevalent in their habitat.

Condition factor can be affected by a number of factors including age, season and maturity stage (Anyanwu *et al*., 2007; Ndome *et al*., 2012; Ayo-Olalusi, 2014). Availability of food and the ability of the fish to convert the food to biomass are also contributory factors (Ndome *et al*, 2012). Other important determinants of the condition factor of fish are reduction in breeding and nursery grounds and pollution (Bakhoum, 1994; Khallaf *et al.*, 2003). The Catfish and Tilapia examined in the present research were harvested from the wild and a condition factor >1 indicates that the fish are able to get adequate nourishment from the water body in the study locations.

It was observed from this study that the condition factor of Tilapia was higher than that of Catfish at each location. For instance, mean K was 1.77 and 2.3 for Catfish and Tilapia respectively at station 1, 1.65 and 2.18 was obtained for Catfish and Tilapia respectively at station 2, 1.54 and 2.18 respectively for Catfish and Tilapia at Station 3, 1.6 and 2.31 respectively for Catfish and Tilapia at Station 4, 1.54 and 2.13 for Catfish and Tilapia at Station 5. This is observation could be because Tilapia does not grow as long as Catfish. This is clearly shown in Table 2 where higher values of both weight and length were recorded for Catfish over Tilapia. For instance, in Okwuzi, mean wet weight was 404.92g and 107.53g for Catfish and Tilapia, respectively.

Similarly, in the same location, mean total length was 28.44cm and 16.73cm for Catfish and Tilapia, respectively. The trend was similar in all locations. As such, the larger weight of Catfish was affected by its longer length to reduce the condition factor, whereas, the lower weight and length of Tilapia made it appear to have a larger condition factor.

However, studies by Haruna and Ipinjolu (2013) on poly-culture of *Clarias* and Tilapia in concrete tanks, showed a higher condition factor ranging 1.87-2.37 for *Clarias* and 0.52-1.7 for Tilapia.

These authors had grouped the fish species in treatments with Clarias: Tilapia ratios of 0:1 (Treatment 1), 1:0 (Treatment 2), 1:2 (Treatment 3), 1:4 (Treatment 4) and 1:6 (Treatment 5).

They found that the highest condition factor of 1.7 for Tilapia and 2.37 for *Clarias* was recorded in Treatment 4. They also found that *Clarias* had maximum length growth (17.92±0.37cm) in Treatment 5 and the lowest (16.6±0.29cm) in the monoculture (Treatment 2). On the other hand, Tilapia had maximum length growth (11.6±0.51) in Treatment 4 and the lowest (4.83±0.41cm) in the monoculture (Treatment 1). They also found that weight gain was best for both species at Treatment 5 (236.20±3.20g and 105.65±3.95g, for *Clarias* and Tilapia, respectively) and lowest for both species (186.34±1.28g and 69.28±0.85g for *Clarias* and Tilapia, respectively) in their monoculture tanks. Their results indicated that Tilapia species actually had better growth condition in the presence of *Clarias* at Clarias: Tilapia ratios of 1:4 and 1:6. Since the present study was carried out in the wild and population ratios of both species in the waters are not available, suffice it to say that the longer length of *Clarias* resulted in their lower condition factor against those of Tilapia.

Comment [A12]: This information should be restated. There is no need to be so detailed, given that the work is published.

Among the Catfish samples, a significantly higher condition factor was obtained at Okwuzi over Ndoni and Omoku. Pollution and anthropogenic activities that cause stress to fish have been shown to adversely affect the condition factor of fishes (Bakhoum, 1994; Khallaf *et al.*, 2003).

Omoku is the headquarter of the LGA and most populated town hosting a lot of people from other areas and small scale industries hence more activities are found to happen in Omoku than other areas of the LGA.

The condition factor of Tilapia did not vary significantly between the stations indicating that differences in environmental conditions at all locations did not affect their physiological condition.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

1. Abowei, J.F.N and Davies, A.O. (2009). Some pollutant parameters of *Clarotes laticep* (Rupell, 1829) from the freshwater reaches of the lower River, Niger Delta,

Nigeria. *American J~~j~~ournal of ~~scientific~~ Scientific Research, 2*: 15-19

2. Abu, O.M.G and Agaria, O.J. (2016). Length – Weight Relationship and condition factor of silver Catfish (*Chrysichths nigrodigitatus*) from the lower Reaches of the new Calabar River, Niger Delta. *International Journal of Innovative Studies in Aquatic Biology and Fisheries,* 2(4), 1-7
3. Anyanwu, P.E., Okoro, B.C., Anyanwu, A.O., Matanmi, M.A., Ebonwu, B.I., Ayabu-Cookey, I.K., Hamzat, M.B., Ihumekpen, F & Afolabi, S. (2007). Length – weight relationship, condition factor and sex ratio of African mud catfish (*Clarias gariepinus)* reared in indoor water re-circulating system tanks. *Research Journal of Biological Science. 2: 780-783*
4. Asonye, C.C., Okolie, N.P., Okenwa, E.E & Iwuanyanwu U.G (2007). Some physicochemical Characteristics and Heavy metal profiles of Nigerian Rivers, Streams and water Ways. *African Journal of Biotechnology*. 6(5):617-624
5. Ayo-Olalusi, C.I. (2014). Length-weight relationship, condition factor and sex ratio of African Mud catfish (*Clarias gariepinus*) reared in flow-through system tanks. Journal of ~~fisheries~~ Fisheries and Aquatic Science, 9(5): 430-434.
6. Bagenal, J.B and Tesch, F.W. (1978a). Methods for assessment of fish production in fresh waters. Oxford, Bladwen scientific publication. P- 360.
7. Bakhoum, S.A. (1994). Comparative study on length–weight relationships and condition factors of the Oreochromis in polluted and non-polluted parts of lake Mariut, Egypt. Bull National Institute of Oceanography and Fisheries Egypt 20:201-210
8. Bolger, T and P.L. Connolly, (1989). The suitable indices for measurement analysis of fish condition. *Journal of Fish Biology, 34(2):171-182*
9. Chukwu K.O and Deekae, S.N (2010), Length-weight Relationship, condition factor and size composition of ~~*periophthalmus*~~ *Periophthalmus barbarous* (Linnaeus 1766) in Calabar River, Nigeria. *Agriculture and Biological Journal of North American.* ISSN Print: 2151-7517. Online: 2151-7525, Doi: 10.525/abjra 2011.2.7.1069.1071.

10. FAO (1983). Compilation of legal limits for hazardous substances in fish and Fishery

product. FAO Fishery Circular No 464. Food and Agriculture Organization; pp. 5-100

11. Frose, R. (2006). Cube law, condition factor and weight-length relationships: History, metal analysis and recommendations. *Journal of ~~applied~~ Applied Ichthyology,* 22:241-253
12. Gullick, R.W., Grayman, W.M., Deininger, R & Males, R.M (2003). Design of early warning Monitoring system of source waters. *Journal of American ~~water~~ Water ~~work~~ Work Association,* 95, 58-72.
13. Haruna, M.A and Ipinjolu, J.K. (2013). Length-weight relationship and condition factor in the poly-culture of Clarias and Tilapia in concrete tanks. *Bayero Journal of ~~pure~~ Pure and Applied Sciences,* 6(2): 132-135.
14. Htun-Han, M. (1978). The reproductive biology of the ~~crab~~ dab *Limanda limanda* (L) in the North Sea: Gonadosomatic index, hepatosomatic index and condition factor. *Journal of ~~fish~~ Fish Biology, 13(1): 351-377.*
15. Idodo-Umeh, G.(2003).Freshwater fishes of Nigeria: Taxonomy, Ecological notes, Diet and utilization. Idodo-Umeh publishers Limited, Edo State, Nigeria.
16. Igwela, K.A., Ahmed, A.B & Abol-Munafi, A.I. (2011). Condition factor as an indicator of growth and feeding intensity of Nile Tilapia fingerlings *(Oreochromis niloticus)* fed on different levels of maltose. *American-European Journal of Agriculture and Environmental ~~science~~Science,* 11(4):559-563.
17. Jisr, N., Younes, G., Sakhn, C & El-Dakdouki, M.H. (2018). Length – weight relationships relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. *The Egyptian Journal of Aquatic Research,* 44(4): 299-305.
18. Khallaf, E.A., Galal, M & Authman, M. (2003). The biology of *Oreochromis niloticus* in a polluted canal. Eco-toxicology, 12: 405-416.
19. Lizama, M.A.P and A.M, Ambrosia (2002). Condition factor in nine species of fish of the Claracidae family in the upper Parana River flood plain. *Brazilian Journal of Biology.* 62: 113-124

20. Ndome, C.B., Eteng, A.O & Ekanem, A.P. (2012) Length –weight relationship and condition factor of the smooth mouth marine fish (*Clarias heudelotii*) in the Gulf of Guinea, Niger Delta, Nigeria. Aquaculture; Aquarium. Conservation and legislation *International Journal of the Bioflux Society. 5(3): 163-167.*

21. Nehemiah, A., Maganira, J.D & Rumisha, C. (2012). Length-weight relationship and condition factor of Tilapia species grown in marine and freshwater ponds. *Agriculture and Biology Journal of North America. 3(3): 117-124*

22. Nwadiaro, C.S and Okorie, P.U (1985). Biometric characteristics, Length/ weight Relationship and Condition Factors in *Chrysichthys filamentosus* (Pisces: Bargridae) from Oguta lake, Nigeria. *Biologia Africana, Vol. 2, No.1, pp 48-57*

23. Obasohan, E.E., Imasuen, J. A & Isidahorne, C.E. (2012). Preliminary studies of the length –weight relationships and condition factor of five fish species from Ibiekuma stream. Ekpoma, Edo State, *Nigeria. E3 Journal of Agricultural Research and Development,* 2(3): 061-069

24. Okwodu, N.E. (2016). Aquaculture for sustainable Development in Nigeria. *Scholars World- International Refereed Multidisciplinary Journal of contemporary Research.* Vol. IV, Issue II P. 76-84. Online ISSN: 2320-3145. Print 1SSN: 2319-5789. www.irmjcr.scholarworld.net

25. Shahabuddin, A.M., Khan, M.N.D., Saha, D., Ayna, E., Wonkwon, K., Murray, W.W., Yoshimatsu, T & Araki, T. (2015). Length-weight relationship and condition factor of juvenile Nile *Oreochromis niloticus* (Linnaeus 1758) fed diets with Pyropia spheroplasts in closed recirculation system. *Asian Fisheries Science. 28(2015): 117-129.*