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Achionye – Nzeh, C.G., Ogidiolu, O. and Salawu, S.S. (2002). Growth response of Juveniles of *Clarias anguillaris* to diet formulated with *Cirina forda* larvae in the laboratory. *Nigerian Journal of Pure and Applied Sciences*. 17:1253 -1256.

Proceedings, Listed Symposia etc

Lamai, S.L., Walker, C.H. and Warner, G.F. (2001). The effects of dieldrin on different life stages of the African catfish *Clarias gariepinus* (Burchell) pp 186 -194. *In*: Eyo, A.A. and Ajao E. A. (Eds). Proceedings of the 14th Annual Conference of the Fisheries Society of the Nigeria, Ibadan, Nigeria. 221p

Books

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STATUS OF FISH FARMING PRACTICES: A CASE STUDY OF SELECTED FISH FARMS IN LAGOS STATE, NIGERIA

*[1]OKUNADE, O. A., [2]G. A. OLADOSU, [1]O. A. ADEOGUN, [3]E. K. AJANI, [4]J. O. ADEJINMI and [1]I. A. AKINTAYO
1. Nigerian Institute for Oceanography and Marine Research, Victoria Island, Lagos State, Nigeria.
2. Department of Veterinary Medicine, University of Ibadan, Oyo State, Nigeria.
3. Department of Aquaculture and Fisheries Management, University of Ibadan, Oyo State, Nigeria.
4. Department of Entomology and Parasitology, University of Ibadan, Oyo State, Nigeria.
*Corresponding author: olumideokunade@yahoo.ca 08034984980

ABSTRACT

Fish is essential in human diet, providing the necessary protein components. In aquaculture, fish are produced under controlled environment to support food security. This study assessed the current status of fish farming practices and identified the available resources and culture management practices deployed for fish production in the aquaculture industry in Lagos State. One hundred fish farms were randomly selected from 3 agricultural zones in Lagos, Nigeria; East, West and Far-East. Structured questionnaires were used for data collection, which were analysed using MS Excel tool and descriptive statistics. Men below 50 years of age constitute 53.08% of overall respondents. Use of boreholes as water source was predominant in the East (92.59%) and West (76.67%), while stream/spring was more in the Far-East (75%). Majority of the fish farms operates small-scale; monoculture of clariid catfish is predominant. The stocking densities of ≤ 100/m³ (fingerlings), ≤ 50/m³ (juveniles and adults) and 2,000/m³ (fry) were estimated in grow-out and hatcheries accordingly. Annual average production of fish seeds were ≤ 100,000 while table sized fish (500 – 999g) was prominent per cycle. Mortality was caused in order of importance: water pollution, infections and feed contamination. Therefore, good aquaculture management practices should be adopted to improve production.

Key Words: Fish culture, Clariid catfish, Current status, Challenges

INTRODUCTION

The inability of capture fisheries to meet global fish demands necessitated the development of aquaculture industry to support the protein needs of the growing population (Committee for Inland Fisheries and Aquaculture of Africa, CIFAA, 2017) which was buttressed by global population projection of about 8.6, 10.1 and 12.7billion by 2030, 2050 and 2100, respectively (UN, 2017). Therefore, fish food production is considered to contribute immensely to global food security (Onyekuru *et al.*, 2019). Fish is crucial for nutrition, food security, and livelihoods by providing the highest-quality protein source and a variety of other nutrients especially essential amino acids and fatty acids that our body needs, in addition to vitamins and other vital elements such as iodine and selenium which are not present in other plants and animal products (Kwasek *et al*., 2020). It accounts for about 17% of the global population's intake of animal protein (Shah and Mraz, 2020).

In Nigeria, the food production and population growth maintain a parallel trend leading to perpetual increase in food insecurity with 2.5% increase in food production while food demand increased above 3.5% as a result of 2.8% increase in population growth (FAO, 2014), leading to low animal protein intake of 6 – 8g per person per day (Iyagbe and Orewa, 2009) as against the minimum recommendation of 36g per person per day (FAO, 2018), culminating in endemic malnutrition (Semba, 2016). However, fish production has been a vital option among the solutions to alleviate the protein deficiency in Nigeria (Ubesie and Ibeziakor, 2012).

Aquaculture provides good protein source in human diet, employment, income generation and good return on investment to farmers (Shava and Gunhidzirai, 2017; Onoja, 2005). Nigeria is endowed with suitable environment to support culture of various fish species (Fact sheet, 2019), and the culturable fish species in Nigeria include Tilapia, *Clarias gariepinus*, *Heterobranchus* sp, Hybrid clariid, *Chrysichthys nigrodigitatus Megalops atlanticus* and *Heterotis* sp., among which the catfish is predominantly cultured followed by the tilapia *sp*. However, the abundant requisite resources for fish culture in Nigeria; natural water sources, extensive coastal area, culturable fish species, diverse feed ingredients and relatively cheaper labour must be adequately harnessed to improve fish production and minimise protein deficiency and malnutrition. A review of the current status of aquaculture practices could reveal areas requiring attention, and proffer solutions toward achieving sustainability in fish production by culture in the country.

MATERIAL AND METHODS

Description of the Study Area

The investigation was carried out in Lagos State, Nigeria (Figure 1). It is the largest coastal state in southwest Nigeria along the Bight of Benin and is 3,345 square kilometers in size. It is situated between longitude $2^0$41'20"E and $4^0$21'10"E and latitude 6°22′10′′N and $6^0$42'15"N (Google Earth Satellite Imagery, 2018). The cardinal boundaries shared with Lagos are with Ogun State on the North and East, the Republic of Benin on the west and coast of the Atlantic Ocean on the south. Lagos State has a humid, dry, wet climate that borders on a tropical monsoon climate. There are two rainy season peaks: the first peak occurs between April and July, followed by a brief respite from precipitation in August and September, and the second peak in October and November. The dry season takes place from December to March, and harmattan is brought on by trade winds from the Sahara Desert in the northeast ("Weather BBC Weather Lagos Nigeria, 2011)

The temperature range in Lagos is between 23°C (74°F) and 34°C (93°F) while the average annual temperature is 27.8ºC (82ºF) with the hottest month being March with a mean temperature of 29.7°C (85.5°F) and the coldest month being August with a mean temperature of 26°C (78.8°F). The wettest month is June, with an average rainfall of 12.2 inches over a period of about 16 days. The driest month is January, with an average rainfall of 0.6 inches over a period of about 2 days (Climatestotravel.com, 2022). The common vocations of indigenous Lagosians include fishing, farming, and livestock rearing, while artisanal fishing is most common in the coastal locations (such as Epe, Badagary, Eleko, and Ikorodu) and inland waterways (Itowolo, Iyana – Oworo, Agboyi and Iwaya). Currently, the state operates three agricultural zones: Lagos East (LE), Lagos West (LW), and Lagos Far – East (LFE).

Data Size and Sampling Procedures

The list of functioning farms was obtained from the Lagos State Agricultural Development Authority (LSADA) and 3% of the fish farms were randomly selected from the list of operating farms to have 54 farms (LE), 30 farms (LW) and 16 farms (LFE) making the total of one hundred (100) fish farms sampled. Structured questionnaires and in-person conversations with farm owners and attendants were used to gather primary data. Each questionnaire's administration with the respondent took an average of 30 to 45 minutes. All of the distributed questionnaires were administered and used for analysis. Socioeconomic factors of the fish farmers, such as their sex, age, education level, marital status, and years of farming experience, are also recorded, along with management techniques like water source, fish species, culture periods, stocking density, biosecurity status, disease awareness, and record-keeping.

Data Analysis

The survey data were sorted and categorized according to the stratified agricultural zones and the corresponding fish farmers. The data were analysed using descriptive statistics (frequency count and percentages) with the MS Excel application.

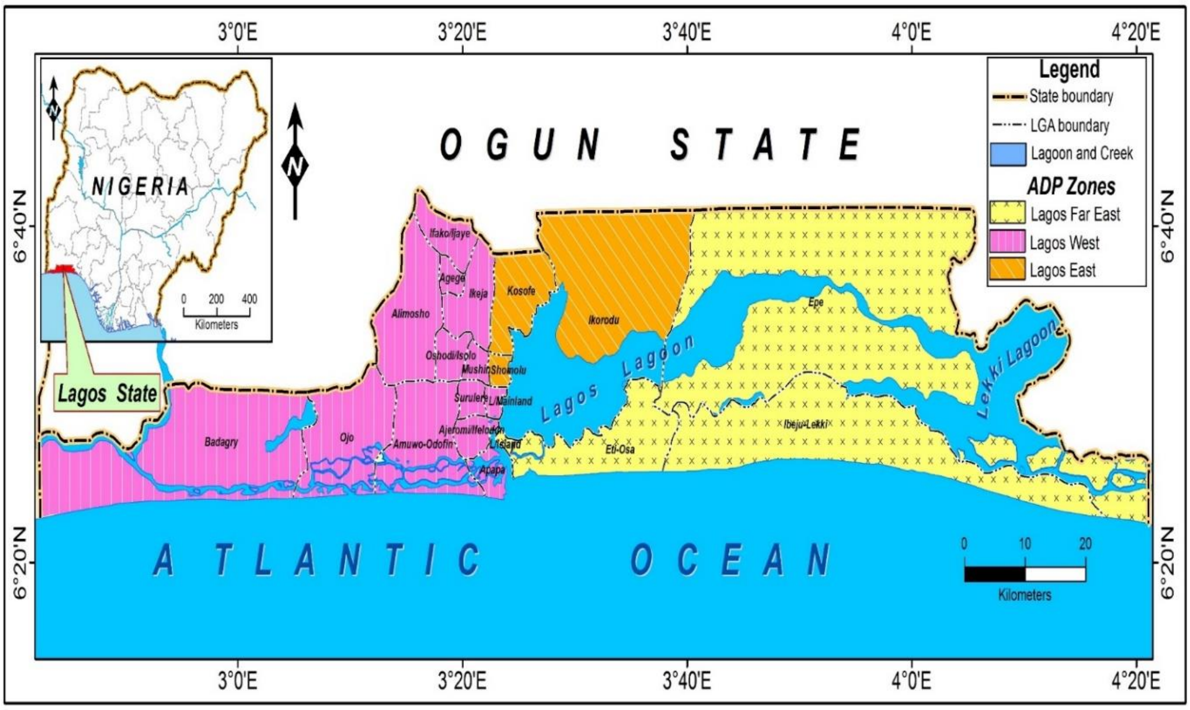

Figure 1: Map of Lagos State showing the three Agricultural Zones

RESULTS

Socio – economic characteristics of fish farmers

Men were more in fish farming compared to women with data in Table 1 showing LE had (85.19%), while LW recorded (86.67%), and LFE (100%). The majority of the respondents were above the age of 50 in LE (40.74%) and LFE (50%) while 50% of those in LW were between the ages of 31 and 40. The majority of farmers in LE (83.19%), LW (100%) and LFE (81.25%) were married. Additionally, the data revealed that 87.04% and 76.67% of respondents raising fish in LE and LW respectively, were graduates while 62.5% respondents in LFE were secondary school leavers. The majority of farmers in LE (70.37%), LW (56.67%), and LFE (56.25%), had 6 to 10 years of experience, whereas 31.25% farmers in LFE, 9.26% in LE and 13.33% in LW had more than 10 years of experience in fish farming.

The management practices in fish farms in Lagos state Management practice and cultured species

Monoculture of clariid catfish was more prevalent throughout all the zones, accounting for 83.33% (LE), 86.67% (LW), and 62.50% (LFE) respondent followed by polyculture of clariid catfish and Tilapia species which were 14.81%, 10%, and 12.50% in LE, LW, and LFE, respectively (Table 2). Along with *Clarias gariepinus*, *Heterobranchus* sp., *Gymnarchus niloticus* and *Heterotis niloticus* were other species raised on the farms. The types of culture facilities available on farms for fish culture varied from earthen ponds to concrete tanks to plastic tanks and tarpaulin vats, with concrete tanks being the most common in LE (50%) followed by tarpaulin vats in LW (30%) and earthen ponds in LFE (75%), a similar pattern was obtained in terms of usage of facilities for fish culture with LE (53.70%), LW (40%) and LFE (75%), respectively (Table 3).

The source of water and pattern of renewal

The sources of water used for fish production were boreholes, well, stagnant ponds and stream (Table 4). Borehole is the major source of water in LE (92.59%) and LW (76.67%), but stream/spring constitute the major source in LFE (75%), which made water readily available for renewal in all the culture facilities. In LE and LFE, 24.07% and 50% of the earthen ponds were renewed weekly respectively while 13.33% were renewed bi – weekly in LW. Farmers in LE (31.48%), LW (23.33%) and LFE (6.25%) renewed their water weekly in concrete tanks while 12.50% (LFE) and 33.33% (LW) farms renewed their water daily. The water parameters were poorly checked in LE (72.22%), LW (83.33%) and LFE (81.25%).

Feed and feeding in the hatchery and grow – out

Most of the farms used commercial feed; 2 different brands for the hatchery and 9 brands for grow – out. Floating feed was mostly used to feed juveniles in LE (33.33%), fry in LW (26.67%) and LFE (18.75%) whereas sinking feed was mostly used to feed juveniles in LFE (31.25%) as well as the combination of feeds in LFE (37.50%) (Table 5). In the hatchery, 50%, 71.43% and 75% of the farmers fed their fish seeds 3 – 4 times daily in LE, LW and LFE respectively, while only 28.57% of the respondents fed more than 4 times in LE. In grow –

out, fish were mostly fed twice daily in LE (60%), LW (56.25%) and LFE (83.33%) but only 25% of the farmers in LE fed fish once daily. In LW, 43.75% respondents fed their fish seeds more than 3 times per day.

The stocking density in hatchery and grow – out production Feed and

The stocking density for fish seeds and grow – out production was represented in Table 6. The culture facilities used in hatchery were concrete tanks, plastic tanks and tarpauling vats. The highest stocking density of > 5,000 fry/m^3 was estimated in concrete tanks in LE to be 3.70%, while density of 2001 – 3,500/m^3 in tarpaulin vats in LW was 10%, but in plastic tanks 6.25% of farms stocked their fry at > 5,000/m^3. In grow – out, 9.26% and 13.33% of farms sampled stocked fingerlings at < 100/m^3, 27.78% and 10% stocked juveniles at < 50/m^3, 22.22% and 6.67% stocked adults fish at < 50/m^3 in LE and LW respectively. Fingerlings were stocked at > 400/m^3 on 6.25% of the farms, while juveniles were stocked at < 50/m^3 on 31.25% of the farms, and 6.25% sampled farms stocked adults fish at < 50/m^3 in LFE.

Scale of operations and production capacity in hatchery and grow – out systems.

The culture periods engaged annually by farmers coupled with respective outputs in hatchery and grow – out systems were shown in Table 7. Most of the farmers producing fingerlings, practiced more than 4 breeding annually having LE = 64.29%. LW = 100% and LFE = 75% while 35.71% and 25% in LE and LFE had maximum of 4 breeding cycles each respectively per annum. The production of fingerlings was on a small scale operations with LE (71.43%), LW (66.67%) and LFE (25%) respondents producing ≤ 100,000 annually but vice versa with medium scale production (101,000 – 1,000,000) having highest respondent in LFE (75%) and least in LE (28.57%). No fish breeder was found in the threshold of large scale production of more than 1,000,000 fingerlings/annum.

In grow – out, most farmers practiced at least 3 cycles annually in LE (62.50%), LW (81.25%) and LFE (83.33%) while 37.50%, 18.75% an 16.67% were on 2 culture periods annually in LE, LW and LFE accordingly. The average weight of fish harvested were graded into 200 – 499g, 500 – 999g and ≥ 1000g with highest average weight at harvest found to be 500 – 999g in LE (70%), LW (81.25%) and LFE (58.33%) whereas fish ≥ 1000g were harvested in 12.50% farms each in LE and LW while 16.67% farms in LFE. Most of the respondents with small scale grow – out operations (0.1 – 6 tons/annum) were found in LFE (69.23%) followed by LE (48.94%). The majority of respondents in LW (61.11%) operated medium scale grow – out (6.1 – 32 tons/annum) followed by LE (40.43%). A similar trend was seen for large scale grow –out production (> 32 tons/annum) with 11.11% farms in LW and 10.64% farms in LE.

The status of biosecurity in fish farms by respondents in Lagos State

The current state of biosecurity measures in fish farms in Lagos State is highlighted in Table 8, where the majority of the measures were compromised by the farmers, such as restriction of visitors to the culture area [LE (9.26%], LW (20%), LFE (18.75%], demarcating the areas of the culture facilities [LE (22.22%), LW (33.33%), LFE (25%), separating the materials used in the culture units [LE (11.11%), LW (46.67%), LFE (18.75%], and providing foot disinfection dip at farm entrance [LE (5.56%), LW (10%), LFE(6.25%)] except the disinfection of culture facilities that were given priority before stocking in LE (87.04%), LW (100%) and LFE (93.75%).

During the cultured periods, the waste water was discharged into nearby canals, drainage channels, self-dug pits and irrigating the vegetable beds. Majority of the farmers in LE (64.81%) and LW (53.33%) discharged their waste water into drainage channels while 50% of farmers in LFE did the same. Different methods were used to dispose their dead fish, including burning, burying, processing to feed fish, throwing into surrounding bushes, processed to dog or cat food, leaving on water to serve as food for fish, and flushing into canals, pits, or adjoining ponds. The majority of farmers in LE (32.31%) and LFE (43.75%) buried their dead fish while 26.15% and 31.25%, respectively left it on water to be eaten by other fish but in LW, most of the farmers (32.26%) flushed their dead fish into nearby canals, pits, or adjacent pond whereas 25.81% respondents chose to bury their dead fish.

The status of disease awareness among fish farmers in Lagos State

The wellness of the fish starts from ability to study fish behavior under culture by noticing any abnormal signs that may need immediate and appropriate attention (Table 9). Most farmers in Lagos State reported daily routing checks for unusual behavior in their fish with LE (88.89%), LW (83.33%) and LFE (100). Although dead fish was occasionally experienced on farms as reported in LE (98.15%), LW (96.67%) and LFE (100%) but when occurred, grow – out were mostly vulnerable in LE (35%), LW (31.25%) and LFE (75%). The most attributable factor contributing to mortality was water pollution in LE (38.17%), LW (42.10%) and LFE (26.06%) followed by infections in LE (31.57%) and LW (23.70%) but feed contamination and other factors in LFE (21.75% each). In LE, LW and LFE, 90.74%, 96.67% and 100% farmers rarely noticed fish infections (Table 10). However, 40.74%, 56.67% and 62.50% farmers mentioned that they experienced fish diseases respectively mostly 50% in dry season (LE), 33.33% and 43.75% in both seasons in LW and LFE accordingly especially on juveniles (43.06%) in LE, fingerlings and grow – out (27.10% each) in LW and grow – out (45.45%) in LFE. Moreover, some farmers in LE (66.67%), LW (43.33%) and LFE (43.75%) had knowledge about fish health and disease control management through vocational training. Inorganic substances (Salt, Oxytetracycline, Furaltadone, Enrofloxacin, Colistin, Aerosol, Phostoxin phosphate, Potassium permanganate, Soda Ash, Ampicilin, Procaine penicillin, Aquaceryl Plus, Kenflox, Keproceryl, NCO (Neomycin, Chloramphenicol and Oxytetracycline), Streptomycin, Flagyl, Fish biotics, Formalin, Lincomycin, Doxycycline, Huwa - san) and/or organic substance (Natural leaves - male pawpaw, bitter, scent, neem, plantain (dry/wet), moringa, garlic, ginger, charcoal, tangiri, smooty (fruit), Super Gro) were used as theurapeutic/prophylactic measure against fish infections. More farmers adopted the use of inorganic substances across the zone (LE – 74.07%, LW – 76.67%, LFE – 81.25%) whereas the use of organic substances is gaining attention in more than 6% farms across the zone.

The status of farm record keeping in hatchery and grow – out systems among fish farmers in Lagos State

Table 11 reported the status of record keeping in hatchery and grow-out farms. Regular farm records that were important to farmers in the hatchery included purchases of input materials (LE 42.86%, 50% each in LW and LFE); stocking rate (LE 57.14%, LW 50%); feeding rate (LE 64.29% and LW 42.86%); sorting (LE 64.29%, LW 100% and LFE 75%); and sales of fish seeds (LE 71.43%, LW 64.29%). However, large numbers of farms did not keep records of water parameters (LE 78.57%, LW 92.86% and LFE 100%); mortality (LE 71.43%, LW 92.85% and LFE 100%) and disease infection (LE 86.71%, LW 86.71% and LFE 100%).

In grow – out farms, water parameter records were rarely kept or ignored in LE by 87.50% farmers, 93.75% in LW and 75% in LFE likewise disease infection records by 85% farmers in LE, 93.75% in LW and 91.67% in LFE. However, most of the farmers kept records of items bought concerning the business as obtained from 90% farmers in LE, 81.25% in LW and 50% in LFE; stocking density kept by 87.50% farmers in LE, 75% in LW and 91.67% in LFE; feeding rate by 72.50% farmers in LE, 43.75% in LW and 41.67% in LFE; sorting records by 65% in LE, 62.50% in LW and 66.67% in LFE and records of sales of table sized fish kept by 95% farmers in LE, 68.75% in LW and 91.67% in LFE.

Table 1: Socio - economic characteristics of fish farmers (n = 100)

Background Characteristics	Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far – East (n = 16)	
	Freq.	%	Freq.	%	Freq.	%
Gender of respondents						
Male	46	85.19	26	86.67	16	100
Female	8	14.81	4	13.33	0	0
Age distribution of respondents (yrs)						
< 21	1	1.85	0	0	0	0
21 – 30	3	5.56	0	0	0	0
31 – 40	9	16.67	15	50	6	37.50
41 – 50	19	35.19	9	30	2	12.50
> 50	22	40.74	6	20	8	50
Marital Status						
Single	7	12.96	0	0	3	18.75
Married	46	85.19	30	100	13	81.25
Widowed	1	1.85	0	0	0	0
Educational Status						
Primary	0	0	0	0	2	12.50
Secondary	7	12.96	7	23.33	10	62.50
Tertiary	47	87.04	23	76.67	4	25
Years of experience						
≤ 1	2	3.70	2	6.67	0	0
2 – 5	9	16.67	7	23.33	2	12.50
6 – 10	38	70.37	17	56.67	9	56.25
> 10	5	9.26	4	13.33	5	31.25

Freq. – Frequency; % - Percentages

Table 2: Mode of management practice and fish species cultured in different facilities

Culture fish and available facilities	Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far – East (n = 16)	
	Freq.	%	Freq.	%	Freq.	%
Type of fish culture						
Monoculture	45	83.33	26	86.67	10	62.50
Polyculture	9	16.67	4	13.33	6	37.50
Culture species reared on farms						
Clariid Catfish (CC)	45	83.33	26	86.67	10	62.50
CC + Tilapia	8	14.81	3	10	2	12.50
CC + Heterobranchus	0	0	0	0	1	6.25
CC + Tilapia + Heterbranchus	1	1.85	0	0	1	6.25
CC + Tilapia + Gymnachus	0	0	0	0	1	6.25
CC + Heterobranchus + Gymnachus	0	0	0	0	1	6.25
CC + Tilapia + Heterotis (Arowana)	0	0	1	3.33	0	0

Table 3: Different culture facilities available in Lagos Agricultural Zones for fish culture

Culture fish and available facilities	Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far – East (n = 16)	
	Freq.	%	Freq.	%	Freq.	%
Culture facilities available on farms						
Earthen ponds (Ep)	15	27.78	5	16.67	12	75
Concrete tanks (Ct)	27	50	4	13.33	1	6.25
Plastic tanks (Pt)	1	1.85	3	10	1	6.25
Tarpaulin vats (Tv)	1	1.85	9	30	0	0
Ep + Ct	0	0	1	3.33	0	0
Ep + Pt	1	1.85	1	3.33	0	0
Ep + Tv	0	0	1	3.33	0	0
Ct + Pt	2	3.70	3	10	2	12.50
Ct + Tv	4	7.41	1	3.33	0	0
Ep + Ct + Pt	1	1.85	0	0	0	0
Ep + Pt + Tv	0	0	1	3.33	0	0
Ep + Ct + Pt + Tv	2	3.70	1	3.33	0	0
Culture facilities with samples collection						
Earthen ponds	15	27.78	5	16.67	12	75
Concrete tanks	29	53.70	8	26.67	1	6.25
Plastic tanks	6	11.11	5	16.67	3	18.75
Tarpaulin Vats	4	7.41	12	40	0	0

Table 4: The source of water used for production of different developmental stages of fish

Source of water and frequency of exchange	Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far - East (n = 16)	
	Freq.	%	Freq.	%	Freq.	%
Source of water						
Borehole	50	92.59	23	76.67	4	25
Well	2	3.70	3	10	0	0
Borehole + Well	0	0	3	10	0	0
Stagnant ponds	1	1.85	1	3.33	0	0
Stream/spring	1	1.85	0	0	12	75
Frequency of water renewal						
Earthen:						
Daily	1	1.85	0	0	0	0
Weekly	13	24.07	1	3.33	8	50
Bi - Weekly	1	1.85	4	13.33	4	25
Concrete tanks						
Daily	11	20.37	1	3.33	0	0
Weekly	17	31.48	7	23.33	1	6.25
Bi - Weekly	1	1.85	0	0	0	0
Plastic tanks						
Daily	3	5.56	2	6.67	2	12.50
Weekly	3	5.56	3	9.99	1	6.25
Bi - Weekly	0	0	0	0	0	0
Tarpaulin Vats						
Daily	2	3.70	10	33.33	0	0
Weekly	2	3.70	2	6.67	0	0
Bi - Weekly	0	0	0	0	0	0
Water Parameters checked:						
Yes	15	27.78	5	16.67	3	18.75
No	39	72.22	25	83.33	13	81.25

Table 5: The type of feeds and the frequency of feeding during culture periods

	Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far - East (n = 16)	
Types of fish feeds used	Freq.	%	Freq.	%	Freq.	%
Floating Feeds						
Fry	8	14.81	8	26.67	3	18.75
Fingerlings	4	7.41	4	13.33	1	6.25
Juveniles	18	33.33	4	13.33	0	0
Adults	13	24.07	2	6.67	0	0
Sinking Feeds						
Fry	0	0	0	0	0	0
Fingerlings	0	0	2	6.67	0	0
Juveniles	0	0	2	6.67	5	31.25
Adults	1	1.85	1	3.33	0	0
Both						
Fry	0	0	0	0	0	0
Fingerlings	2	3.70	3	9.99	0	0
Juveniles	5	9.26	4	13.32	6	37.50
Adults	3	5.56	0	0	1	6.25
Feeding Frequency						
Hatchery						
1 - 2 Times	3	21.43	4	28.57	1	25
3 - 4 Times	7	50	10	71.43	3	75
> 4 Times	4	28.57	0	0	0	0
Grow - Out						
1	10	25	0	0	0	0
2	24	60	9	56.25	10	83.33
≥ 3	6	15	7	43.75	2	16.67

Table 6: The stocking density in hatchery and grow – out production systems in Lagos State

Stocking Density (m^3)		Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far - East (n = 16)	
		Freq.	%	Freq.	%	Freq.	%
Hatchery (Estimation)							
Concrete tanks:	< 500	1	1.85	0	0	1	6.25
	501 - 2,000	0	0	0	0	0	0
	2001 - 3,500	0	0	0	0	0	0
	3,501 - 5,000	1	1.85	0	0	0	0
	> 5000	2	3.70	0	0	0	0
Plastic tanks:	< 500	1	1.85	1	3.33	0	0
	501 - 2,000	1	1.85	0	0	1	6.25
	2001 - 3,500	0	0	0	0	0	0
	3,501 - 5,000	1	1.85	0	0	0	0
	> 5000	0	0	1	3.33	1	6.25
Tarpaulin Vat:	< 500	0	0	0	0	0	0
	501 - 2,000	0	0	1	3.33	0	0
	2001 - 3,500	0	0	3	10	0	0
	3,501 - 5,000	0	0	1	3.33	0	0
	> 5000	1	1.85	1	3.33	0	0
Grow – out							
Fingerlings:	< 100	5	9.26	4	13.33	0	0
	100 - 200	0	0	0	0	0	0
	201 - 300	1	1.85	0	0	0	0
	301 - 400	0	0	0	0	0	0
	> 400	0	0	1	3.33	1	6.25
Juveniles:	< 50	15	27.78	3	10	5	31.25
	51 - 100	6	11.11	0	0	0	0
	101 - 150	0	0	0	0	0	0
	151 - 200	2	3.7	1	3.33	0	0
Adults:	< 50	12	22.22	2	6.67	1	6.25
	51 - 100	3	5.56	0	0	0	0
	101 - 150	1	1.85	0	0	0	0
	151 - 200	1	1.85	1	3.33	0	0

Table 7: Scale of operations and production capacity in hatchery and grow – out systems in Lagos State.

Culture period and production per annum	Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far - East (n = 16)	
	Freq.	%	Freq.	%	Freq.	%
Culture periods per annum						
Hatchery						
1 to 4	5	35.71	0	0	1	25
≥ 4	9	64.29	14	100	3	75
Grow - Out						
1 to 2	15	37.50	3	18.75	2	16.67
≥ 3	25	62.50	13	81.25	10	83.33
Average numbers of fish seeds produced per annum (estimation)						
≤ 100,000	5	71.43	8	66.67	3	75
101,000 – 1,000,000	2	28.57	4	33.33	1	25
> 1,000,000	0	0	0	0	0	0
Average weight harvested (g)						
200 - 499	7	17.50	1	6.25	3	25
500 - 999	28	70	13	81.25	7	58.33
≥ 1000	5	12.50	2	12.50	2	16.67
Scale of Operations						
Hatchery						
Small	5	71.43	8	66.67	3	75
Medium	2	28.57	4	33.33	1	25
Large	0	0	0	0	0	0
Grow - Out						
Small	23	48.94	5	27.78	9	69.23
Medium	19	40.43	11	61.11	3	23.08
Large	5	10.64	2	11.11	1	7.69

Freq. – Frequency; % - Percentages

Table 8: The status of biosecurity in fish farms by respondents in Lagos State

Biosecurity Measure		Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far – East (n = 16)	
		Freq.	%	Freq.	%	Freq.	%
Restriction to culture area	Yes	5	9.26	6	20	3	18.75
	No	49	90.74	24	80	13	81.25
Demarcation of culture facility areas	Yes	12	22.22	10	33.33	4	25
	No	42	77.78	20	66.67	12	75
Separation of culture unit materials	Yes	6	11.11	14	46.67	3	18.75
	No	48	88.88	16	53.33	13	81.25
Provision of foot disinfection dip at entrance	Yes	3	5.56	3	10	1	6.25
	No	51	94.44	27	90	15	93.75
Disinfection of culture facilities before stocking	Yes	47	87.04	30	100	15	93.75
	No	7	12.96	0	0	1	6.25
How do you discharge waste cultured water	Nearby Canal	15	27.78	10	33.33	8	50
	Drainage Channel	35	64.81	16	53.33	6	37.50
	Self dug pit	2	3.70	2	6.66	0	0
	Irrigation for vegetable	2	3.70	1	3.33	2	12.50
	Others	0	0	1	3.33	0	0
Disposal of dead fish	Burnt	1	1.54	1	3.23	0	0
	Buried	21	32.31	8	25.81	7	43.75
	Processed to feed fish	3	4.61	4	12.90	0	0
	Left to be fed by fish	17	26.15	3	9.68	5	31.25
	Processed for dog/cat	2	3.07	3	9.68	0	0
	Thrown to nearby bush	9	13.85	1	3.23	3	18.50
	Flushed to pond/canal/pit	11	16.93	10	32.26	0	0
	Others	1	1.54	1	3.23	1	6.50

Table 9: Routine observation of behavioural signs and possible factors to fish mortality in culture systems

	Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far – East (n = 16)	
Factors of mortality	Freq.	%	Freq.	%	Freq.	%
Checking the unusual signs in fish behaviours						
Daily	48	88.89	25	83.33	16	100
Weekly	0	0	2	6.67	0	0
Fortnightly	1	1.85	0	0	0	0
Rarely	5	9.26	3	10	0	0
How often do you pick dead fish						
Regularly	0	0	1	3.33	0	0
Occasionally	53	98.15	29	96.67	16	100
Never	1	1.85	0	0	0	0
Suspected causes of mortality						
Infection	24	31.57	9	23.70	4	17.38
Water pollution	29	38.17	16	42.10	6	26.06
Feed Contamination	11	14.48	6	15.80	5	21.75
High Stocking Density	6	7.89	2	5.27	2	8.69
Electricity challenges	3	3.94	0	0	0	0
Sudden change in weather	0	0	1	2.63	0	0
Natural (Flood)	1	1.31	0	0	1	4.38
Others	2	2.63	4	10.53	5	21.75

Table 10: The status of disease awareness among fish farmers in Lagos State

Disease Awareness features	Lagos East (n = 54)		Lagos West (n = 30)		Lagos Far – East (n = 16)	
	Freq.	%	Freq.	%	Freq.	%
Disease Occurrence						
Yes	22	40.70	17	56.67	10	62.50
No	32	59.30	13	43.33	6	37.50
Rate of infection occurrences						
Always	1	1.85	0	0	0	0
Occasionally	49	90.74	29	96.67	16	100
Never	4	7.41	1	3.33	0	0
Season with infection						
Rainy	11	20.37	10	33.33	3	18.75
Dry	26	48.20	9	30	6	37.50
Both	14	24.07	10	33.33	7	43.75
None	3	5.56	1	3.33	0	0
Developmental Stages infection						
Fry	9	12.50	12	25	4	18.19
Fingerlings	10	13.89	13	27.10	2	9.09
Juveniles	31	43.06	9	18.77	6	27.28
Adults	19	26.39	13	27.10	10	45.45
None	3	4.17	1	2.10	0	0
Infected fish taken for laboratory diagnosis						
Hatchery	2	14.29	1	7.14	1	25
Grow - out	4	10	2	12.50	0	0
Knowledge about fish health and disease control management through vocational training						
Yes	36	66.67	13	43.33	7	43.75
No	18	33.33	17	56.67	9	56.25
Treatment/prevention of infection/clinical signs of fish						
Inorganic application	41	75.93	25	83.33	14	87.50
Organic applications	2	3.70	1	3.33	0	0
Both	3	5.56	4	13.33	1	6.25
None	4	7.41	0	0	1	6.25

Table 11: Record keeping in hatchery and grow – out farms

Farm Record Keeping	Hatchery						Grow – Out					
	LE(n = 14)		LW (n = 14)		LFE (n = 4)		LE (n = 40)		LW (n = 16)		LFE (n = 12)	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Procurement (inputs)												
Always	6	42.86	7	50	2	50	36	90	13	81.25	6	50
Occasionally	5	35.71	5	35.71	1	25	4	10	0	0	4	33.33
Never	3	21.43	2	14.29	1	25	0	0	3	18.75	2	16.67
Water Parameters:												
Always	3	21.43	1	7.14	0	0	5	12.50	1	6.25	3	25
Occasionally	7	50	6	42.86	2	50	25	62.50	8	50	2	16.67
Never	4	28.57	7	50	2	50	10	25	7	43.75	7	58.33
Stocking Rate												
Always	8	57.14	7	50	1	25	35	87.50	12	75	11	91.67
Occasionally	4	28.57	4	28.57	1	25	3	7.50	2	12.50	0	0
Never	2	14.29	3	21.43	2	50	2	5	2	12.50	1	8.33
Feeding Regime												
Always	9	64.29	6	42.86	0	0	29	72.50	7	43.75	5	41.67
Occasionally	4	28.57	6	42.86	2	50	7	17.50	7	43.75	6	50
Never	1	7.14	2	14.29	2	50	4	10	2	12.50	1	8.33
Sorting												
Always	9	64.29	14	100	3	75	26	65	10	62.50	8	66.67
Occasionally	3	21.43	0	0	0	0	6	15	6	37.50	4	33.33
Never	2	14.29	0	0	1	25	8	20	0	0	0	0
Mortality												
Always	4	28.57	1	7.14	0	0	14	35	5	31.25	9	75
Occasionally	6	42.86	8	57.14	1	25	14	35	9	56.25	1	8.33
Never	4	28.57	5	35.71	3	75	12	30	2	12.50	2	16.67
Disease infection												
Always	2	14.29	2	14.29	0	0	6	15	1	6.25	1	8.33
Occasionally	4	28.57	4	28.57	1	25	15	37.50	5	31.25	0	0
Never	8	57.14	8	57.14	3	75	19	47.50	10	62.50	11	91.67
Sale												
Always	10	71.43	9	64.29	1	25	38	95	11	68.75	11	91.67
Occasionally	3	21.43	3	21.43	2	50	2	5	3	18.75	0	0
Never	1	7.14	2	14.29	1	25	0	0	2	12.50	1	8.33

LE – Lagos East; LW – Lagos West; LFE - Lagos Far – East; Freq. – Frequency; % - Percentage

DISCUSSION

Socio – economics Characteristics of fish farmers

Majority of the farmers across the zone were males with few female (LE-14.81%, LW-13.33% and LFE-0%) indicating that fish farming demands masculine disposition due to labour intensive nature of the aquaculture industry, especially pond constructions, water discharge by water pumps, harvesting, sampling and so on which agreed with the findings of (Omitoyin and Osakuade, 2021; Omeje *et al.,* 2020; Ukpe *et al*., 2017). Involvement of different ages was observed among farmers in Lagos State indicating no age discrepancy in fish farming though the involvement of youth below 30 years were few only in LE signifying possible dwindling of young people from fish farming probably by diversifying from agriculture into other businesses or lack of starting funds. Overall, at least 50% of the respondents in each zone were between 31 – 50years representing the economically active age group similar to the report of (Akarue and Aregbor, 2015; Oluwasola and Ige, 2015). Above 80% of the respondents were married which may possibly ascertain the viability and sustainability of the business by striving to channel workable strategies towards productivity and profitability which agreed with the findings of Omitoyin and Osakuade (2021), Thompson and Mafimisebi (2014) and Omitoyin and Sanda (2013). Majority of the respondent had tertiary education which may contribute to ease of understanding and implementation of new innovations to increase technical efficiency of production, conforming to Igwe (2004) and Onyenweaku *et al*. (2005).

Assessment of production activities

Farming activities management

Borehole was the main source of water in LE and LW thereby making the farmers to adopt concrete tanks, plastic tanks, tarpaulin vats and combinations of two culture facilities which ascertained durability and afford them the opportunity of continuous production throughout the year. Also, these facilities could increase the expected technical efficiency of the farm (Igwe *et al*., 2011). The earthen ponds frequently used in LFE could be associated to the availability of stream and spring water for fish production which was considered cheaper than borehole. The findings in LE and LW were contrary to Shitote *et al*. (2013), with 82.80%, 16.70% and 0.50% farmers depending respectively on spring or stream as the water sources, indicating that the source of water depend on the geographical location of the farm site.

Clarias gariepinus was the main fish cultured across the zones which is in compliance with 90% fish farmers in Delta metropolis reported by Okpeke and Akarue (2015), 81% in Jos (Wuyep and Rampedi, 2018) and 61% in Calabar (Ele *et al.,* 2013). This may be due to attributable factors of the fish coupled with market value and consumers' acceptability. Earthen ponds were mostly used in LFE (Epe axis) probably because of high water table as a result of the surrounding waters while tarpaulin vats were frequently used in LW since it's a sandy environment and cost effective compared to construction and maintenance of concrete and plastic tanks. Many farmers invested in culture facilities but operated minimally by using few numbers because of insufficient fish seeds and increase in the cost of feeds.

The stocking densities of the fry were maintained at varying capacity based on the system adopted. The capacity of 2,000 fry per m^3 was reported in DWR partially agreed with the reports of Viveen *et al*. (1985) and Hecht *et al*. (1988). The common stocking density for juveniles was $\leq 50/m^3$ partially conformed to 7 – 100 catfish juveniles/m^3 (Ofor and Afia, 2015) and 4 – 12 catfish juveniles/m^3 (Abou – Zied, 2015). This indicates that farmer possibly stocked their facilities based on available resources and expected yield.

Most of the farmers in LE (79.63%) and LW (60%) predominantly used floating feeds probably because of the culture facilities (concrete tanks, plastic tanks and tarpaulin vats) commonly used while combination of both floating and sinking (43.80%) in LFE with most farms using earthen ponds unlike the varieties of feeds reportedly used with locally formulated feeds (48.80%) highly used (Adebo and Ayelari, 2011). In hatcheries, average of 65.50% breeders fed their fish three to four times per day while average of 66.40% grow out farmers fed their fish twice a day indicating the commitment of farmers in providing feeds despite the increase in cost of fish feeds contrary to 28.40% respondents that fed their grow out fish twice a day (Adeogun *et al.,* 2007).

However, the stocking density at juvenile and adult stages were similar which indicates that most of the final stocking density was done at juvenile stage and reared to the point of harvest (author per. comm.). The harvesting weight commonly sold among farmers across the zones ranged between 500 – 999g which was similar to the weight of fish (420 – 850g) sold at farm gate reported by Hecht, (2013). This may be due to the incessant increase in the price of fish feeds as well as the market demand. Nevertheless, lower stocking density was considered as a significant factor to growth performance and survival rate of *C. gariepinus* (Hecht *et al*., 1996) as well as high stocking densities possibly enhance the fish yield aggregate without much effect on mortality rate (Khatune-Jannat *et al.*, 2012; Pouey *et al*., 2011; Sorphea *et al*., 2010).

Small scale operation was predominant in hatcheries across the zones probably due to insufficient quality broodstocks coupled with local demands of fish seeds from neighbouring farms and self-stocking of grow – out facilities. No farm engaged in large scale operation of fish seeds production possibly because of high technical – know – how required with assurance of regular availability of broodstocks. In grow – out production, LW recorded farms with highest medium and large scale productions which could be due to ability to harness all their culture facilities with quality seeds under intensive management practices.

Farming experience, biosecurity and diseases

More than 55% farmers in each zone had 6 – 10 years of fish farming experience with at least 9% farmers with more than 10 years, similar to the findings of Ifejika *et al*., (2007). Increase in the years of experience was expected to be an impetus to succeed in fish farming (Dey *et al*., 2002; Edward, 2000) and reduces management risk (Krause, 1995). However, the responses of most farmers to biosecurity were so poor thereby supporting the report of Faye *et al*. (2020) with 86.40% respondents showing less concern to biosecurity due to lack of knowledge and understanding of the importance of the measure on production. More so, the impressive educational status and years of experience of most farmers recorded were supposed to aid the understanding of aquaculture procedures for effective management of fish farms rather failed the compliance assessment with a very low rate, which may be as a result of negligence to farm hygiene and noncompliance to standard biosecurity rules and regulations (Ngueguim *et al*., 2020; Shitote *et al*., 2013).

Moreover, ability to observe fish behaviour in captivity and identify any unusual symptoms that may require attention is the first step in ensuring the wellbeing of fish. The importance of specialised training on fish health and disease control attended by most farmers in LE could be responsible for the least infections recorded while Lagos Far – East has the highest number of farmers without fish health training, indicating inability to respond effectively to fish disease challenges. However, awareness of fish diseases will help fish farmers identify signal of pathogenic risk and possible intervention to apply immediately. Juveniles were highly prone to infections as recorded in this study probably due to the stage being frequently stocked which means that they might be transferred with infection from the farms where procured (Okere and Adeyemo, 2014). Only few farmers across the zones took their infected fish for laboratory diagnosis despite claiming to have received vocational training on fish health and disease control probably because the existing laboratory is far from them or insufficient veterinarian or fish expert within the localities to attend to their immediate challenges.

CONCLUSION

Fish farmers in Lagos State were of different ages with men being prominent. The predominantly cultured fish species was *Clarias gariepinus*, reared in earthen ponds, concrete tanks, plastic tanks and tarpaulin vat using boreholes (or spring and stream in earthen ponds). Few farmers engaged in breeding of fish seeds while majority produced table sized fish of average weight of 750g in 3 – 4 times (or more) culture periods per annum. The stocking density for juveniles was $< 50/m^3$ and formulated feeds were commonly used in hatchery and grow – out farms with daily feeding of 3 – 4 times in hatchery and 2 time in grow – out. Most of the hatcheries and grow – out were operated on small scale except medium scale in LW grow – out. Farmers assumed that mortality was due to poor water conditions mostly, and infections rarely, since disease diagnosis were rarely carried out. Majority of the farmers showed negligence to biosecurity measures and record keeping of most farming activities. However, the varied practices among fish farmers showed that the systems (hatchery and grow –out) are not standardized which possibly resulted to different mode of operations during the cultured periods. Therefore, it would be of importance for policy makers and stakeholders to present and affirm the best management practices for fish farmers as operational guidelines with periodic fish farming trainings to assess compliance.

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REFERENCES

Abou-Zied, R. M. (2015). Effect of stocking density and diet's type on productive performance and economic efficiency of African catfish *Clarias gariepinus* under semi-intensive system. *Egyptian Journal of Animal Production*. 52(3):163-172

Adebo, G. M., and Ayelari, T. A. (2011). Climate Change and Vulnerability of Fish Farmers in Southwestern Nigeria. *African Journal of Agricultural Research* 6 (18): 4230 – 4238.

Adeogun, O. A., Ogunbadejo, H. K., Ayinla, O. A., Oresegun, A., Oguntade, O. R., Alhaji Tanko and Williams, S. B. (2007). Urban Aquaculture: Producer Perceptions and Practices in Lagos State, Nigeria. *Middle-East Journal of Scientific Research* 2 (1): 21 – 27.

Akarue .O. B. and Aregbor O. E. (2015). Socio-economic analysis of catfish farming in Uvwie Local Government Area, of Delta State, Nigeria. *International Journal of Innovative Agriculture and Biological Resources* 3 (3):33-43, 2015

Climatestotravel.com: Lagos Guide - Retrieved 18 March, 2022.

Committee for Inland Fisheries and Aquaculture of Africa [CIFAA] (2017). Status of inland fisheries and aquaculture in Africa (CIFAA/XVII/2017/4). Banjul, Gambia. Retrieved from http://www.fao.org/fi/staticmedia/MeetingDocuments/CIFAA/CIFAA17/4e.pdf

Dey, M. M., Rab, M. A., Paraguas, F. J., Prumsombun, S., Bhatta, R., Alam, F. M., Koeshendrajana, S. and Ahmed, M. (2002). Socio – economics of freshwater fish farm in Asia: Strategies and options for increasing and sustaining fisheries and aquaculture production to benefit poor households in Asia. File///A1/fish supply and demand in Asia progress report. WorldFish Center, pp 1 – 14.

Edward, P. (2000). Aquaculture, poverty impacts and livelihood. *Oversea Development Institute*. 56: 1 – 8.

Ele, I. E., Ibok, O. W., Antia – Obong, E. A., Okon, I. E. and Udoh, E. S. (2013). Economic Analysis of Fish Farming in Calabar, CrossRiver State, Nigeria. *Greener Journal of Agricultural Sciences*: Vol. 3(7), pp. 542 – 549

Fact Sheet, (2019). Aquaculture in Nigeria, 1 – 2pp

Faye, R., Diouf, N. D., Ly, M. A., Ayih-Akakpo, J. A. (2020). Biosecurity Practices Applied in Aquacultural Farms in Northern Senegal, West Africa. *European Scientific Journal*, 16 (6): 286 – 299.

Food and Agriculture Organisation (FAO) (2014). Economic analysis of supply and demand for food up to 2030—special focus on fish and fishery products. FAO Fisheries and aquaculture Circular 1089. FIPM//C1089 (En), FAO, Rome, Italy, 20 pp.

Food and Agriculture Organisation (FAO) (2018). Dietary Assessment: A resource guide to method selection and application in low resource settings, Food and Agriculture Organisation of the United Nations, Rome, Italy. 2018. ISBN 978-92-5-130635-2, 172 pp

Google Earth Satellite Imagery (2018). Extraction of Lagos State positioning from the open street map of Lagos State and Google earth satellite imagery.

Hecht, T., Uys, W. and Britz, P.J., eds. (1988). The culture of sharptooth catfish, *Clarias gariepinus* in southern Africa. South African National Scientific Programmes Report No. 153. Pretoria, Council for Scientific and Industrial Research. 133 pp.

Hecht, T. (2013). A review of on-farm feed management practices for North African catfish (*Clarias gariepinus*) in sub-Saharan Africa. In M.R. Hasan and M.B. New, eds. On-farm feeding and feed management in aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 463 – 479.

Hecht, T., Oellermann, L., Verheust, L., (1996). Perspectives on clariid catfish culture in Africa. *Aquatic Living Resources* 9, 197–206.

Ifejika, P. L., Ayanda, J. O. and Sule, A. M. (2007). Socio – economic variables affecting aquaculture production practices in Borgu Local Government Area of Niger State, Nigeria. *Journal of Agriculture and Social Research (JASR)* 7 (2): 20 – 29.

Igwe, K. C. (2004). Technical Efficiency and its Determinants of Yam Production in Nasarawa State, Nigeria. An MSc Thesis Submitted to the Department of Agricultural Economics, Michael Okpara University of Agriculture,

Umudike Igwe, K. C., Echebiri, R. N., Nlewadim, A. A. and Anorue, P. C. (2011). Application of the stochastic production frontier to the measurement of technical efficiency of fish farming in Umuahia metropolis, Abia State, Nigeria. *Journal of Agriculture and Food Sciences*. Volume 9, Number 1, pp. 1-8.

Iyangbe, C. O. and Orewa, S. I. (2009). Determinants of Daily Protein Intake among Rural and Low – Income Urban Houses in Nigeria. *American-Eurasian Journal of Scientific Research*, 4(4): 209 – 301.

Khatune-Jannat, M., Rahman, M. M., Bashar, M.A., Hasan, M.N., Ahamed, F. and Hossain, M. V. (2012). Effects of stocking density on survival, growth and production of Thai Climbing Perch (*Anabas testudineus*) under fed ponds. *Sains Malaysiana* 41: 1205–1210.

Krause, M. (1995). *Practical farming: Rural property planning risks management*. Australia. Reed International Books, Pp 9 and 18.

Kwasek, K., Thorne – Lyman, A. L. and Phillips, M. (2020). Can human nutrition be improved through better fish feeding practices? A review paper. *Critical Reviews in Food Science and Nutrition* 60:3822–3835. https://doi.org/10.1080/10408398.2019.1708698

Ngueguim, D. F., Kouam, M. K., Tiogue, C. T., Miegoue, E., Feumba, A. K., Zebaze, L. B. F. and Awah-Ndukum, J. (2020). Prevalence and associated risk factors of ectoparasite infections of cultured fish species in the West region of Cameroon. *International Journal of Fisheries and Aquatic Studies* 8(3): 310 – 320.

Ofor, C. O. and Afia, O. E. (2015). Effect of Stocking Densities on Growth and Feed Utilization of Hybrid Catfish (*Clarias gariepinus* X *Heterobranchus longifilis*) Fed at 1% Body Weight. *American Journal of Biology and Life Sciences*. 3(6): 211 – 217

Okere, N.C. and Adeyemo, O. K. (2014). Occurrence and fish farmer perceptions of symptoms of diseases in Ibadan and Ikorodu in Nigeria. *African Journal of Animal and Biomedical Sciences,* 8(1): 82-88

Okpeke, M. Y. and Akarue, B. O. (2015). Analysis of The Profitability of Fish Farming in Warri South Local Government Area of Delta State, Nigeria. IOSR *Journal of Agriculture and Veterinary Science* (IOSR-JAVS): Volume 8, Issue 12 Ver. I, PP 45-51. e-ISSN: 2319-2380, p-ISSN: 2319-2372. www.iosrjournals.org.

Oluwasola O. and Ige A.O. (2015). Factors determining the profitability of catfish production in Ibadan, Oyo State, Nigeria. *Sustainable Agriculture Research* 4 (4), 57–65.

Omeje, J. E., Sule, A. M. and Aguihe, E. O. (2020). An assessment of aquaculture table-size fish farmers activities in Kainji Lake Basin, *Nigeria. Agro – Science*, 19 (2), 36-40. DOI: https://dx.doi.org/10.4314/as.v19i2.6

Omitoyin, S.A., Osakuade, K.D. (2021). Awareness and Constraints of Aquaculture Biosecurity Among Fish Farmers in Ekiti State, Nigeria. *Aquaculture Studies*, 21: 83 – 92. http://doi.org/10.4194/2618-6381-v21_2_05

Omitoyin, S.A. and Sanda, O.H. (2013). Sources and Uses of Micro-Credit in Poverty alleviation among fish farmers in Osun state, Nigeria. *Journal of Fisheries and Aquatic Sciences* 8(1):154 -159

Onoja, G. O. (2005). Fish and poverty. Agribus Today.: 1(8):5–7.

Onyekuru, N. A., Ihemezie, E. J. and Chima, C. C. (2019). Socioeconomic and Profitability Analysis of Catfish Production: a case study of Nsukka Local Government Area of Enugu State, Nigeria. *Agro-Science,* 18 (2): 51-58.

Onyenweaku, C. E., Igwe, K. C. and Mbanasor, J. A. (2005). Application of the Stochastic Frontier Production Function to the Measurement of Technical Efficiency in Yam Production in Nasarawa State, Nigeria. *Journal of Sustainable Tropical Agriculture Research* 13: 20-25

Pouey, J. L.O.F., Piedras, S.R.N., Rocha, C.B., Tavares, R.A., Santos, J.D.M. and Britto, A. C. P. (2011). Productive performance of silver catfish, *Rhamdia quelen*, juveniles stocked at different densities. *Ars Veterinaria* 27: 241–245.

Semba, R. D. (2016). The rise and fall of protein malnutrition in global health. *Annals of Nutrition and Metabolism* 69(2): 79 – 88. doi:10.1159/000449175

Shah, B. R. and Mraz, J. (2020). Advances in nanotechnology for sustainable aquaculture and fisheries. *Reviews in Aquaculture* 12:925–942. https://doi.org/10.1111/raq.12356

Shava, E. and Gunhidzirai, C. (2017). 'Fish Farming as an Innovative Strategy for Promoting Food Security in Drought Risk Regions of Zimbabwe', *Jàmbá: Journal of Disaster Risk Studies 9*(1): 491.

Shitote, Z, Wakhungu, J. and China, S. (2013). Challenges Facing Fish Farming Development in Western Kenya. *Greener Journal of Agricultural Sciences* 3(5):305 – 311.

Sorphea, S., Lundh, T., Preston, T. R., Borin, K., (2010). Effect of stocking densities and feed supplements on the growth performance of tilapia (*Oreochromis* spp.) raised in ponds and in the paddy field. *Livestock Research for Rural Devevelopment* 22: 227.

Thompson, O. A., and Mafimisebi, T. E. (2014). Profitability of Selected Ventures in Catfish Aquaculture in Ondo State, Nigeria. *Fisheries and Aquaculture Journal, 5*(2):096.

Ubesie A. C, Ibeziakor N. C. (2012). High burden of protein-energy malnutrition in Nigeria: beyond the health care setting. *Annals of medical and health sciences* 2(1):66–69.

Ukpe U. H., Audu N. D., Djomo C. R. F. and Akise O. G. (2017). Economics of catfish farming in selected Local Government Areas of Taraba State, Nigeria. *Innovative Techniques Agriculture* 23: 376 – 382.

United Nation (2017). Department of Economic and Social Affairs. Accessed from: https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.htmlon 5/8/2020

Viveen, W.J.A.R., Richter, C.J.J., Van Oordt, P.G.W.J., Janssen, J.A.L. and Huisman, E.A. (1985). Practical manual for the culture of the African catfish (*Clarias gariepinus*). The Hague, The Netherlands

Ministry for Development Cooperation, Section for Research and Technology. 128 pp.

"Weather BBC Weather Lagos Nigeria".BBC.Retrieved 15 July 2011.

Wuyep, S. Z. and Rampedi, I. T. (2018). Urban fish farming in Jos, Nigeria: Contributions towards employment opportunities, income generation, and poverty alleviation for improved livelihoods. *Agriculture* 8, 110p.; doi:10.3390/agriculture8070110

TECHNICAL EFFICIENCY OF TABLE SIZE CATFISH PRODUCTION IN KAINJI LAKE BASIN, NIGERIA

[1]ILESANMI, Z. F., *[1] P.I. IFEJIKA, [2] A. MUHAMMAD-LAWAL, [1] J.E. OMEJE, [3]L.I. IFEJIKA AND [4] I. A. ENWELU

[1]Socio-Economics and Extension Services Division
National Institute for Freshwater Fisheries Research (NIFFR)
P.M.B. 6006, New Bussa, Niger State, Nigeria.
Emails: ifejikaphilip@gmail.com
+2347089523717
[2]Department of Agricultural Economics and Farm management,
University of Ilorin, P.M.B. 1515, Kwara State, Nigeria.
[3]Department of Home and Rural Economics
Federal College of Freshwater Fisheries Technology
New Bussa, Niger State.
[4]Department of Agricultural Economics and Extension
Nnamdi Azikwe University, P.M.B. 5025, Awka, Anambra State

ABSTRACT

The study investigated the technical efficiency of catfish table size production under intensive system among cluster fish farmers in Kainji Lake Basin. Multistage sampling procedure was deployed to select 120 respondents for the study from three clusters namely Monai, Fakun and New Bussa in 2020. Primary data were collected with semi structured questionnaire and analyzed using descriptive statistics and Cobb-Douglas regression analysis to determine technical efficiency of table size catfish production in the study area. Findings showed that the catfish table size entrepreneurs are mostly men (86%) with mean age of 38 years. Majority (96%) are marriedand educated (72.5%) with 40.83% having household size of 4-5 persons with good fish farming experience ($\bar{x}$=5years). Majority (99%) use earthen ponds while 94% farm hybrid (hetero-clarias) species. Total number of fingerlings was 970,600 stocked in a 47,493m^2 size of ponds and fed with 741,060kg feed. The significant production efficiency factors were type of ponds, farming experience, household size, years of education, marital status, age, size of ponds and labour. Therefore, improving production efficiency in the area requires adherence to stocking density, mentoring young fish farmers, and adoption of best aquaculture practices. In addition, post fingerlings should be stocked in earthen ponds supported with technical knowledge through training, embracing agribusiness management and marketing principles to ensure profitable return on enterprise and sustainability as well as cooperative approach to overcome common issue.

INTRODUCTION

Practitioners' business orientation towards commercial fish farming in the production value chain activity is the driving force on visible impact of catfish culture to the economy in terms of job and wealth creation, gross domestic product, food nutrition security as well as good image as a leader in sub-Saharan region. Aquaculture contributes up to 30% of total domestic fish production in the country with 316,727 metric tonnes in 2021(Global Panel on Agriculture and Food Systems for Nutrition (2022). According to Food and Agricultural Organization (FAO) reported in Daily Trust Newspaper, (2021), Nigeria's aquaculture industry monetary value has risen from ₦23 billion investment in 2006to ₦261.8 billion in 2022, contributing about one million direct jobs in the value chain. Also, ECOWAS report (2020) showed that aquaculture production in Nigeria rose from 143.21 metric tonnes in 2008 to 291.32 metric tonnes in 2018 and now 316,727 metric tonnes in 2021 (Global Panel on Agriculture and Food Systems for Nutrition, 2022). All these indicate positive change and increase in production with more capacity to meet domestic fish need.

As aquaculture production intensify, practitioners of catfish farming sought for cost effective production techniques to leverage on at minimal cost. In Kainji Lake basin, particularly in New Bussa and surrounding communities with concentration of fish clusters, aquaculture activities in catfish production has been nurtured and grown with visible impact on life of aquapreneurs. Recent study in New Bussa, Kainji Lake basin on aquaculture performance cited by Olaosebikan (2021) showed that between July 2019, and February 2020, a total of 32,340 cartons of smoked fish worth ₦1,746,360,000.00 billion were transported to Onitsha market in Anambra state from New Bussa, Niger state, whereas another investigation of 12 middlemen showed an estimated 7,680 tonnes of live table size catfish worth ₦5,030,400,000.00 billion were sold from Kainji lake basin at the market price of ₦655/kg. On profitability of enterprise, Omeje *et al.* (2021a) empirically established that catfish farming in Kainji lake basin is a viable business with high return on investment of 71.81%, 51.05% and

109.27% for the men, women and youths respectively implying that to every ₦ 1.00 invested in table-size fish farming, about 77.38 kobo (average value) will be realized as profit ceteris paribus. Above evidence indicates that aquaculture farmers are to an extent technically efficient in utilizing production inputs and their human capital, but not yet to the maximum potential.

Efficiency implies the ability of a firm to realize maximum output from the given set of inputs. It is the ratio of output to input and the greater the ratio, the more the magnitude of technical efficiency (Girei *et al*., 2014; Ohen *et al*., 2014). Hence, a production process is technically inefficient if it does not produce maximum output from a given set of inputs and is therefore operating below its production frontier. According to Jarzebowski (2013), efficiency studies help countries to determine the extent to which they can raise productivity by improving efficiency with the existing resource base and available technology. In this direction, Onoja and Achike (2011) asserted **that f**ish production system in Nigeria is faced with low technical efficiency. In South-West zone with active aquaculture entrepreneurs, Esobhawan and Reuben (2010) pointed out that fish farms operate below optimal frontier production level, of whose efficiency level can be improved by a range of 20-40%. Also, Ifejika *et al.* (2022) noted that fish **f**armers manage to produce table size catfish more efficiently at lower cost with farm made pelletized feed. On production system, Oluwatayo and Adedeji (2019) study concludes that the most efficient and profitable construction designs among earthen, cage culture and plastic tank is the earthen pond.

According to Ebukiba *et al*. (2022), the acute shortage of production inputs has been complicated by gross inefficiency in resource use. In spite of the growing number of Catfish farmers in Kainji Lake Basin, Catfish production in Nigeria is not efficient. This is because the demand for fish still outweighs its supply in Nigeria (Liverpool-Tasie *et al*., 2021). This led to the spending of over 288 billion naira annually on fish importation in Nigeria (Central Bank of Nigeria, 2017). This implies that much need to be done on the technical efficiency of Catfish production. Also, the limited information on the prevailing circumstances on technical efficiency pre-empted the study on technical efficiency of catfish production in Kainji Lake Basin, Nigeria. Specifically, the study described the socio-economic variables; examined the table size Catfish production inputs and determined the technical efficiency of table size catfish production.

MATERIALS AND METHOD

Study Area, Data Collection and Analysis

This study was carried out in Kainji Lake basin on coordinates $10^0 22$'N $4^0 33$'E. Fishing is one of the attributes of the lake basin which is on decline for some decades. The Kainji lake axis of Borgu local government area is the center for aquaculture hub in Niger state with two federal fisheries institutions on research and human capital training, clusters of fish farm, more than 30 farm-made pelletizing fish feed producers, and recent multimillion tilapia cage culture on the lake by private investor. In the past 15years, catfish farming has risen as a flourishing rural enterprise in New Bussa and environ contributing to fish food supply to cities, job creation, wealth in the value chain, and training of fisheries undergraduates on practical field experience as documented by Ifejika *et al*. (2007; 2021), and Omeje *et al.* (2021b).

The study used a three-stage sampling technique. The first stage is the purposive selection of Borgu local government area based on the availability of clusters of fish farms in the Niger state axis of the lake. Second stage was purposive selection of New Bussa, Monai, and Fakun communities based on the concentration of clusters of fish farms in those communities. Third stage was the random selection of 120 respondents from the three clusters of fish farm communities thus; 30 table size fish farmers were selected from New Bussa, 60 from Monai and 30 fish farmers from Fakun the population of 185 table size fish farmers. Primary data were collected using semi structured questionnaire which were administered to the respondents through face to face interview. Collected data were on the socioeconomic characteristics and production inputsused to determine technical efficiency. Analytical tools deployed were descriptive statistics of mean and percentages to describe socio-economic variables of age, experience, household size, membership of association, gender, education, and marital status. For technical efficiency, the model is expressed below:

Technical Efficiency Model Specification

There is an assumption that farmers maximize expected profits. Following this, Cobb-Douglas stochastic production model was used in a single equation below to analysis technical efficiency of catfish farmers. The appropriateness of Cobb-Douglas model for testing efficiency of catfish production system is based on the assumption that Cobb-Douglas model methodology has self-duality of choice.

$$\text{In } Y_i = \beta_0 + \Sigma^5_{i=1} \beta \ln X_i + (v_i - \mu_i)$$

Where;

Y_i= quantity of catfish output in kilogram (kg)

X_1= total numbers of labour used measured in man days (family and hired labour)

X_2= size of pond used (m^2)

X_3= quantity of feed used (kg)
X_4= cost of other materials: such as hormones, fuel, farm land rent, additives and depreciation costs, cost of chemicals, and electricity (₦)
X_5= quantity of fingerlings stocked (kg)
μ= a non-negative random variable associated with farm-specific factors which contribute to farms not achieving maximum efficiency
V = a stochastic error term (including extreme weather, measurement errors; and other noise errors such as misspecification problems; poaching industrial action) β_o= constant parameter
β_i= coefficients to be estimated; ln= natural logarithm

RESULTS

Presented below are the results and findings of the study on respondents' socioeconomic characteristics, and technical efficiency of catfish table size production.

Table 1: Socio-Economic Characteristics of Table Size Fish Farmers (N= 120)

Variables	Percentage (%)	Mean
Age		39
Less than 30	25.00	
31-40	28.00	
41-50	38.00	
Above 51	9.00	
Gender		
Male	86.00	
Female	14.00	
Marital Status		
Single	4.17	
Married	95.83	
Educational Level		
Educated	72.50	
Non-educated	27.50	
Household Size		5
Less than 4	33.33	
4 – 5	40.83	
6 -7	22.50	
Above 7	3.33	
Years of Fish Farming Experience		5
Less than 6	69.17	
6 - 10	24.17	
11 - 15	5.00	
16 above	1.67	
Membership of Fish Farmers Group		
Yes	37.70	
No	62.30	

Source: Field Survey, 2020

Socio-Economic Characteristics Variables

The result of socio-economic characteristics is presented in Table 1. Result on gender showed involvement of men and women in catfish production activities, however, men (86%) are the dominant gender with high level of investment in catfish farming than the women (14%). On the age distribution, mean age was 39 years which signifies high involvement of young people (19-40 years) in catfish farming enterprises. The most dominant active age group were people in middle adulthood between 41-50 years (38%) followed by young age category 31-40 years (28%) and youths below 30 years (25%). Information on marital status of respondents showed that 95.83% were married while 4.17% are single. On household size, the mean household size was 5 persons whereas 40.83% have household size of 4-5 persons, while 22.5 % had 5-6 household size, and 3.33% had household size of more than 7 persons.

Respondents' education showed that 72.5% have the ability to read and write as educated respondents compared to uneducated (27.5%) without formal education. Responses on years of experiences indicated that most of the sampled farmers (69%) have less than 6 years of experience followed by 24% with 6-10years experience, while 7% had at least11years experience. Less than half (37.7%) belong to fish farmers' association against 62.3% as none members in the area. Low membership of cooperative association affects formidable cooperative activities on monitoring and price control of fish for profitable enterprise in the area.

Production Inputs of Table Size Fish Farmers

Adequate production inputs ensure high survival rate, productivity and profit venture, hence the verification on choice of pond type and size, quantity of fish stocked, feed type and quantity used. As shown in Table 2, earthen pond was the most preferred pond type used by respondents (99%) followed by concrete ponds (1%). On pond size, 47,493m^2 was the size of the entire ponds used by the fish farmers (120 fish farmers). Response on fish species cultured and quantity of fish stocked revealed that *hetero-clarias was* the major (94 %) fish species cultured by the fish farmers followed by *Clarias gariepinus species* (5%) called butch. On stocking density, respondents stocked 970,600 fingerlings with an average of 6,560 fingerlings per pond measuring 147.95m^2. The result on feed type revealed intensive usage of both extruded and pelletized feed by all respondents. Whereas on feed quantity, it shows the usage of 741,060kg of both feeds (extruded feed =18,855kg and pelletized feed =722,235kg) till maturity which is usually 6 months.

2: Table Size Catfish Production Inputs

Variables	Value	Mean
Type of ponds (%)		
Earthen	99%	
Concrete	1%	
Total pond size (m^2)	47,493m^2	147.95m^2
Catfish Species stocked (%)		
Hybrid (*hetero-clarias*)	94%	
Clarias garipinus	5%	
Heterobranchus bidorsalis	1%	
Total number of Fingerlings stocked (number)	970,600	6,560
Fish Feed Types Used (Kg)		
Pelletized farm made feed	722,235	6018.62
Extruded feed	18,855	157.12

Technical efficiency of catfish production

The results presented in Table 3 shows the OLS regression estimate offactors that affect catfish production. The Cobb-Douglas functional form was used given that the data analyzed was a production data. The results showed that the F-statistic of 73.16 was statistically significant at 1% level of significance. The R-square of 0.8914 implies that about 89% of the variation of the dependent variable is accounted for by the independent variables included in the model. The remaining 10.86% not explained could be attributed to factors beyond the farmers' control as well as variables not included in the model. The estimated coefficients of the pond type and size were positive and significant at 1% and 5% levels of significance respectively. Further results showed that labour was positively and significant in increasing the efficiency of the table size catfish farmers at 5% level of significance. For the production inefficiency variables, the results revealed that fish farming experience, household size and educational level had negative signs and were significant at 1% levels of significance in influencing the efficiency of the farmers in catfish production in the area. More years of farming experience means more perfection in application of skills and allocation of scarce resources; whereas, large farming household size could provide cheap source of labour thereby reducing cost of production. Formal education on the other hand, encouragesfarmers to accept agricultural innovations that could increase their level of efficiency. Contrarily, results showed that marital status and ages of farmers had positivesigns and were significant at 1%, levels of significance influencing the efficiency of the farmers in catfish production in the area. Similarly, the result for age implies that the farmers are less likely to improve in catfish production efficiency as they become older.

Table 3: Factors determining the efficiency of catfish production

Variables	Coefficient	Standard Error	T-value	P> t
Production Variables				
Type of ponds	0.0889	0.0170	5.24***	0.000
Total size of ponds	0.0345	0.0137	2.52**	0.013
Skill labour in month	0.0442	0.0186	2.38**	0.019
Pelletized local feed used	0.0090	0.0222	0.41	0.685
Extruded foreign Feeds used	-0.0055	0.0160	-0.34	0.731
Number of fingerlings stocked	-0.0092	0.0258	-0.36	0.722
Inefficiency Variables				
Years of fish farming experience	-0.0661	0.0098	-6.72***	0.000
Household size	-0.2570	0.0192	-13.41***	0.000
Educational level	-0.0839	0.0154	-5.44***	0.000
Marital status	0.1485	0.0349	4.25***	0.000
Gender	0.0307	0.0200	1.54	0.127
Age	0.5255	0.0273	19.23***	0.000
Constant	-1.6312	0.2464	-6.62***	0.000
Diagnostic Statistics				
F-statistic	73.16***			
R-squared	0.8914			

Source: Field data analysis 2020
** =significant at 0.05, ***=significant at 0.01

DISCUSSIONS

On gender involvement, finding justify that men (86%) are harnessing the economic opportunities more than women in table size value chain of aquaculture, probably due to access to capital for investment, stamina to carryout daily tasking job activities, and perseverance to wait for 4-6 months before fish harvest and high return as profit and income. This finding was consistent with Ifejika *et al.* (2007) finding on men as active fish farmers, thus confirming that the status quo has not changed after 18years on men domineering pond fish culture in the Kanji lake basin. From the result, youth (25%) involvement in catfish enterprise has recorded remarkable improvement compared to only 7% recorded 18years ago in the area (Ifejika *et al*., 2007). Profitability of enterprise is the driving force for men folk to engage in table size catfish farming to meet family responsibilities and argument income by actors like traders, pensioners, civil servants, health workers, housewives and politicians. It has been established that most catfish farmers use family labour which serves as source of learning and induction into fish farming enterprise (Ifejika, 2015). In agreement with finding were Omeje *et al.* (2021b) on the mean household size of 5 persons which can be of great importance in meeting the labour requirements of fish farming such as feeding, environmental sanitation and the like. Most respondents are educated (72.5%) in the area. A high literacy level in aquaculture has been established to enhance the management of fish farms through the adoption of improved farm practices (Agboola, 2011). Therefore, educational status of catfish farmers is a necessary pre-requisite to support adoption of innovations and techniques to increase productivity, economic benefit and interaction with digital tools for technical knowledge and management. In this study, about 31% had over six years of experience which can be attributed to wealth of knowledge gained over the years which can be used to navigate challenges as well as share with others during meetings, mentor beginners, and take informed technical decisions in the enterprise. Baruwa and Omodara (2019) agreed that fish farming experience is a vital human capital for productivity growth in catfish production as found in Oyo state. Respondents’ membership of local association of fish farmers is low as few (37.7%) joined existing Borgu Fish Farmers’ Cooperative Society and Borgu Catfish Association of Nigeria, New Bussa branch. This is seen as a challenge for them to enjoy economy of scale to tackle issue of high cost of feed, unstable fish price, insecurity, theft and government interventions.

Also, the result on production inputs of table size fish farmers showed a high adoption and preference of earthen pond. This is due to its rich source of natural fish food of zooplanktons which adds to fish growth and productivity as well as the availability of land with water retention capacity near river banks. This finding agrees with earlier results of Ifejika *et al*. (2007) on the high adoption of earthen ponds for fish farming in the area. This is also justified by Oluwatayo and Adedeji (2019) that the most efficient and profitable construction designs among earthen, cage culture and plastic tank is the earthen pond method. Because of this, the demand for land for aquaculture has increased as well as cost of land by 250% in most communities like Monai, Old Awuru, Yuna, New Bussa, Sabo

Pegi, within the area in the past 10 years (Ifejika *et al*., 2022). The finding on the fish species stocked agrees with Ifejika *et al*. (2007) that most fish farmers stock hybrid catfish (*Hetero clarias*). The choice of adoption and stocking of hybrid catfish is because *Hetero clarias* grows bigger over time and gives processors more "fish cuts" to sell compared to pure *Clarias* species. The result on stocking density implies that the fish farmers over stock their ponds with fingerlings. The stocking density did not conform to standard of10/$m^2$for *Clarias species* as recommended by Ovie and Ovie (2014). The overstocking of ponds usually results to cannibalism, poor growth, unhealthy competition for feed and space, fish death, water quality issues and loss of revenue. Adequate input and management practices ensure high survival rate, productivity and profitable venture.

Findings on production efficiency established that the model has strong explanatory power, that is, there was a significant relationship between the dependent variable and the independent variables included in the model. It also showed that the coefficient of multiple determinations (R-squared) was 0.8914. This implies that 89.14% variation in the table size catfish farmers' production was explained by the explanatory (production and inefficiency) variables included in the model. This suggests that the level of production among the catfish farmers is being influenced by the high use of earthen ponds and size of their ponds in relation to stocking density. The variable (pond type) and (size of ponds) were significant at ($p<0.01$) and ($p<0.05$) respectively which implies that a unit increase in the type and size of the ponds will likely lead to improvement in the quantity of output of the catfish farmers in the area. This agrees with Oluwatayo and Adedeji (2019) that the most efficient and profitable construction designs for fish farming is the earthen ponds. Also, the variable (labour) was significant at ($p<0.05$) whichimplies that a unit increase in labour utilization by one man-day will increase the likelihood of observing an increase in the farmers' technical efficiency. The quality and quantity of labour input represents the care given to the catfish farm which could enhance the productivity of the farmers. Earlier studies in the area attest to high use of family and hired labour in carrying out fish farm activities such as feeding, sampling and harvesting (Ifejika, 2005; and Omeje *et al.*, 2021a). For the production model, it means that an increase in these explanatory variables will likely reduce the level of production inefficiency among the catfish farmers in the area. This implies that these independent variables included in the production model have the potentials to improve the technical efficiency of the farmers. For the inefficiency model, the variables such as years of farming experience, household size and years of education had negative signs and were significant at ($P<0.01$). This implies that a unit increase in these variables will result to a decrease in inefficiency of fish farmers; hence, an increase in the efficiency of fish farmers. Variables such age and marital status had positive signs and were significant at ($P<0.01$) which means that an increase in age will result to inefficiency of farmers whereas, fish farmers that are married are more likely to be more efficient in catfish production than their single counterparts.

CONCLUSION

Empirical evidence from the study showed positive changes and progress over the years in the multi-million catfish table size enterprise. As revealed, there is remarkable increase in active involvement of youths in fish farming. Also, practices showed the use of improved technologies and inputs like fingerlings, extruded and pelletized feeds, and earthen ponds to increase production and yield. However, over stocking of ponds with fingerings practices undermine technical efficiency which should be replaced with best practices on stocking density for better productivity. Notwithstanding, the study showed high technical efficiency among fish farmers even though there is room for improvement with best technical and agribusiness aquaculture practices.

RECOMMENDATIONS

Based on the emerging evidence from the study, there is need for continuous capacity building through sensitization and technical training to upgrade knowledge, business orientation and management practices among practitioners for better yield and profit to sustain aquaculture enterprises. Fisheries institutions like National Institute for Freshwater Fisheries Research (NIFFR), Federal College for Freshwater Fisheries Technology (NIFFR) and farmers' groups like Catfish Farmers Association of Nigeria (CAFAN) and Fisheries Society of Nigeria (FISON) operating in the area should form synergy on capacity building to help improve technical efficiency. Also, catfish farmers should adopt the stocking of juvenile and post-juvenile fingerlings, avoid overstocking and improve quality of pelletized feed for better results and return on investment.

REFERENCES

Agboola, W. L., (2011). Improving fish farming productivity towards achieving food security in Osun State, Nigeria: A socio-economic analysis. *Annals of Biological Research*, 2(3), 62–74.

Baruwa, O.I. and Omodara, O.D. (2019) Technical Efficiency of Aquaculture system in Oyo State, Nigeria: Stochastic Frontier Approach. *Journal of Aquatic Research & Marine Sciences*, 114-120.

Central Bank of Nigeria (2017). Annual Report.

Daily Trust Newspaper (2022). Why Nigeria's ₦261.8b Catfish Industry is in Danger. Sunday March 2022, https://dailytrust.com/why-nigerias-n261-8bn-catfish-industry-is-in-danger/

Daily Trust (2021). Inside Kwara Multi-Million Naira Catfish Business. Sunday, May 2, 2021

Directorate of Agriculture and Rural Development – ECOWAS Commission, "Fishery and Aquaculture: Statistical Factsheets of the ECOWAS Member countries", August 2020, 32-33

Ebukiba, E., Akpeji, G. and Anthony, L. (2022). Technical efficiency analysis of Melon (*Coloncynthiscitrullus* 1) production among smallscale farmers in federal capital territory, Nigeria. *Int. J. Agric For Life Sci*. 6(1), 18-23.

Esobhawan A, and Reuben AA (2010). Economic Efficiency of Aquaculture Production in Edo State, Nigeria, 2-9. IFET 2010 Montpellier Proceedings. file:///C:/Users/user/ Downloads /442-1.pdf

Global Panel on Agriculture and Food Systems for Nutrition (2022). Transformation and future of aquatic food systems in Nigeria. *Policy brief on the july 2021 national dialogue*, September 2022. 1-23. glopan.org

Girei, A. A., Dire, B., Yuguda, R. M. and Salihu, M. (2014). Analysis of productivity and technical efficiency of cassava production in Ardo-Kola and Gassol Local Government Arears of Taraba State, Nigeria. *Agriculture, Forestry and Fisheries*, *3*(1), 1-5

Ifejika, P.I. (2015). Assessment of fish farmers' information behaviour towards mobile phone innovative platform services in selected states of Nigeria. PhD thesis, Department of agricultural extension and rural development, Ladoke Akintola University of Technology, Ogbomoso, Oyo State.

.

Ifejika, P.I., Ayanda, J.O. and Sule, A.M. (2007). Socio-Economic Variables Affecting Aquaculture Production Practices in Borgu L.G.A. of Niger State, Nigeria. *Journal of Agriculture and Social Research,7* (2), 20-29.

Ifejika1, P.I., Ibenu1, B.A., Omeje1, J.I., Garba, A. U., and Umar, J.K. (2021). Survey of Fish Feed Entrepreneurship and Impact in New Bussa and Surrounding Communities. *Proceedings of the 36th annual national conference of fisheries society of Nigeria (FISON). held in Port Harcourt, Rivers state.* 482-488.

Ifejika, P.I., Ilesanmi, Z.F., Ifejika, L.I., Belonwu, E.N., Olowosegun, T. and Abdullahi, J.Z**.** (2022). An Appraisal of Aquaculture Value Chain Activities in Kainji Lake Basin, Nigeria. *Proceedings of the 37th annual national conference of fisheries society of Nigeria (FISON), held in Adamawa state, November 2022.*

Liverpool-Tasie, S., Sanou, A., Reardon, T., and Belton, B. (2021). Demand for imported versus domestic fish in Nigeria. *Journal of Agricultural Economics*, *72*(1), 1-23.

Ohen, S., Ene, D. and Umeze, G. (2014). Resource use efficiency of cassava farmers in Akwa Ibom State, Nigeria. *Journal Biology Agriculture and Healthcare*, *4* (2), 126-131

Olaosebikan, B.D. (2021). Aquaculture: Then and now in kainji lake basin. Presentation at the inauguration of fisheries society of Nigeria (FISON), New Bussa branch, 1st September 2021. 1-15.

Omeje, J. E**.,** Achike, A. I.,Sule, A. M. &Arene, C. J. (2021a). Gender roles and economic differentials in aquaculture of Kainji Lake Basin, Nigeria. *Research on World Agricultural Economy*, *2*(2), 1-10.

Omeje, J. E., Achike, A. I., Arene, C. J., Faleke, S. A., Manuwuike, Q. C. and Usman, G. A. (2021b). Socio-economic determinants of net-income in fish farming in kainji lake basin, Nigeria. *Global journal of agricultural sciences*, *20*, 53-61.

Onoja A.O., and Achike, A. I (2011) Resource productivity in small-scale Catfish (*clarias gariepinus*) farming in Rivers State, Nigeria: A translog model approach. *Journal of Agricultural Social Research*, *11*, 139 – 146.

Oluwatayo, I.B. and Adedeji, T.A. (2019). Comparative analysis of technical efficiency of catfish farms using different technologies in Lagos State, Nigeria: a

Data Envelopment Analysis (DEA) approach. *Agriculture and Food Security*, 8, 8

Ovie, S.O and Ovie, S.I (2014). Aquaculture in Focus. Second edition. 68-69.

Jarzebowshi S. (2013). Parametric and non-parametric efficiency measurement: the comparison of results. *Quant Methods Economics*. *14*(1), 170–9.

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SAFETY ASSESSMENT OF CRUDE AND AQUEOUS EXTRACTS OF *Syzygium aromaticum* in *Oreochromis niloticus* (Linnaeus, 1758) JUVENILES

[1]DUROJAIYE, A.F., [2]S.O. OBASA, AND [1]A.S. OLUSESI
[1]Department of Forestry, Wildlife and Fisheries, Olabisi Onabanjo University, Ago-Iwoye.
[2]Department of Aquaculture and Fisheries Management, Federal University of Agriculture Abeokuta.
Corresponding author: fadilatdurojaiye@oouagoiwoye.edu.ng +234 7051383411

ABSTRACT

The application of plant extracts in aquaculture is growing due to their various biological benefits; however, some are toxic. This study was carried out to evaluate the safety doses of S. aromaticum (clove buds) in O. niloticus juvenile. Air dried buds were pulverized to obtain crude powder while aqueous extraction was done following standard method to obtain aqueous extract. Median lethal dose (LD_{50}) was determined using Lorke's method. Behavioural responses were monitored and recorded. When crude powder was administered, there was no adverse reaction observed in the first 6 hours at doses below 1000mg/kg while reactions like weak swimming, loss of scale and fin erosion were noted at increased doses. In the group administered aqueous extract, no adverse responses were recorded in the first 6 hours. Beyond this period, ragged fins, slow opercular movement and loss of scale were observed even at the lowest dose of 10mg/kg. The calculated LD_{50} for crude powder was 223.61mg/kg and 538.52mg/kg for aqueous extract. Conclusively, the LD_{50} values recorded in this study indicate moderate toxicity. It is recommended that S. aromatica be used with caution and the calculated LD_{50} should not be exceeded to avoid toxic responses from fish.

Keywords: Clove, Safety, Lethal dose, Toxicity, Fish health

INTRODUCTION

Medicinal plants have been used as a source of herbal remedies in human traditional medicine (Mishra *et al*., 2013; Murugan *et al*., 2021) and many have been reported to possess pharmacological activities that are attributable to the presence of bioactive compounds such are glycosides, saponins, flavonoids, steroids, tannins, alkaloids, terpenes (Batiha *et al.*, 2018; Beshbishy *et al.*, 2019). In traditional use, the extent of application of an herb ensures that a corresponding herbal drug is safe. However, traditional or folk medicine comprises practices, approaches, knowledge and beliefs not based on scientific evidence that are applied to treat, diagnose and prevent illness. Hence, there is need for cautious use as some herbal remedies can be toxic (Mounanga *et al*., 2015; Schultz *et al*., 2020; Olaniyi *et al.*, 2020).

In recent decades, medicinal plants have been gaining wider acceptance in aquaculture due to the perception that these plants being natural products, have lesser side effects and improved efficacy than their synthetic counterparts (Ody, 2017; Ruddaraju *et al*., 2020). *Syzygium aromatica* is commonly known as clove. In Nigeria, it is commonly called "kanufari" and "kanafuru" by the Hausas' and Yorubas' respectively, and used as a health spice in food and drinks such as 'yaji' (grilled meat sauce), 'kunu zaki' (millet drink), and 'jedijedi' (herbal concoction). Agbaje *et al*. (2009) reported that the flower bud of the plant has spermicidal effect in male rats, hence, can be a potential anti-fertility feed additive in controlling prolific breeding in *Oreochromis niloticus.* However, there are some medicinal plants that are toxic (Antache *et al.*, 2013), hence, there is need to ascertain the phyto-toxicity of *Syzygium aromatica* in fish.

Ascertaining the toxicity of medicinal plants in fish production can be challenging, whereas, several strategies including genotoxicity and carcinogenicity assessments have been employed to mitigate this problem in mammalian cells (Kirkland *et al*., 2016; Li *et al.*, 2019; Allemang *et al*., 2021). However, another strategy is the use of LD_{50}, also called the median lethal dose. The value of LD_{50} for a substance is the dose required to kill half the members of a tested population after a specified test duration. LD_{50} is usually determined by tests on animal models or cells. LD_{50} tests on laboratory mice (Kouadio *et al*., 2014; Olatunbosun *et al*., 2018) and fish (Sreedevi and Vijayalakshmi, 2018; Jobi and Kshetrimayum, 2020; Ojetayo *et al*., 2022) have been conducted.

To the best knowledge of the authors, there are no studies presently that have examined LD_{50} of

S. aromatica extracts (crude and aqueous) in *O. niloticus.* To this end, the focus of this study is to examine LD_{50} of *S. aromatica* extracts in *O. niloticus.* Findings from the study will serve as a guide on safe inclusion levels of *S. aromatica* extract in further applications in fish nutrition.

MATERIALS AND METHODS

Procurement and identification of clove buds

The study was carried out at the Department of Forestry, Wildlife and Fisheries, College of Agricultural Sciences, Olabisi Onabanjo University, Ayetoro Campus. *S. aromatica* was procured from a reputable market in Ibadan, Oyo State, Nigeria. The plant (bud) was identified and authenticated in the Forestry unit in the Department of Forestry Wildlife and Fisheries.

Procurement of experimental Fish

One hundred and fifty *O. niloticus* juveniles were purchased from a reputable farm in Ikorodu and transported in oxygen bags to the laboratory. They were acclimatized for two weeks under laboratory condition while being fed twice daily with commercial fish feed. The fish were kept in aerated 1000L tanks containing freshwater and the water was drained partially and refilled every alternate day.

Preparation of *S. aromatica* (powder and aqueous)

The collected clove buds were rinsed in clean water and air dried at room temperature for 14 days (Obaroh and Nzeh, 2013). The air dried buds were pulverized to powder using an electric blender machine. The powder obtained was weighed (550g) and half of this was used to prepare the aqueous extract. For aqueous extraction, powdered buds sample obtained was soaked at ratio 1:12 clove to water at room temperature for 72 hours with constant mixing within this period (Ojetayo *et al*., 2022). The resulting extract was filtered with sterile muslin cloth and concentrated using water bath.

Determination of LD_{50}

LD_{50} was determined following Lorke's method (Lorke, 1983). This method involved two phases. In Phase 1, nine fish samples were required. The nine fish samples were divided into three groups and each group had three fish. Each group of fish were administered 10mg/kg, 100mg/kg and 1000 mg/kg of test substance (powder and aqueous extract). The fish were placed under observation for 24 hours to monitor their behaviour and mortality. For Phase 2, three fish samples were distributed into three groups of one fish each. Each group were administered 1600mg/kg, 2900mg/kg and 5000 mg/kg of clove powder and aqueous extract and then observed for 24 hours for behaviour as well as mortality. Then the LD_{50} was calculated by the formula:

$$LD_{50} = \sqrt{D_0 \times D_{100}}$$

Where:

D_0 = Highest dose that gave no mortality,

D_{100} = Lowest dose that produced mortality

RESULTS

Behavioural responses of *O. niloticus* administered crude clove buds

Behavioural responses of fish administered crude clove are presented in Table 1. In the first 6 hours of Phase 1, fish administered 10mg/kg of crude clove showed no adverse reaction; in the 12th hour, normal opercular movement and ragged fins were recorded and in the 24th hour, weak swimming movement and ragged fin with mortality was recorded. In fish administered 100mg/kg of the test ingredient, in the first 6th hour, no adverse reaction was observed; in the 12th hour, normal opercular movement and mild fin erosion were observed and in the 24th hour, weak opercular movement, pronounced fin erosion with mortality were recorded. In fish administered 1000mg/kg of test ingredient, no adverse reaction was observed in the first 6 hours; in the 12th hour, mild fin erosion was noted and in the 24th hour, weak swimming, mild fin erosion with mortality were recorded. In Phase 2, the group administered 1600mg/kg of test ingredient exhibited upside down swimming in some fishes and laboured breathing in the first 6 hours; in the 12th hour, scale loss was recorded and in the 24th hour, scale loss, and mortality were recorded. In group administered 1600mg/kg of the test ingredient, no adverse reaction was observed in the first 6 hours; in the 12th hour, pronounced fin erosion and slow opercular movement were observed and in the 24th hour, pronounced fin erosion, slow opercular movement and no mortality were recorded. In the group administered 5000mg/kg of crude clove, in the first 6 hours, weak swimming movement was observed; in the 12th hour, pronounced scale loss, abnormal swimming and pronounced fin erosion was recorded and in the 24th hour, pronounced scale loss, weak swimming, pronounced fin erosion but no mortality was observed.

Behavioural responses of *O. niloticus* administered clove buds aqueous extract

The result of behavioural responses of *O. niloticus* administered clove buds aqueous extract is presented in Table 2. In fish fed with 10mg/kg of test ingredient, in the first 6 hours, no adverse reaction was observed; in the 12th and 24th hour, ragged fins and slow opercular movement were observed. In fish fed with 100mg/kg of test ingredient, no adverse reaction was observed in the first 6 hours post administration; in the 12th and 24th hour post administration, ragged fins with slow opercular movement were observed and mortality was recorded. In fish fed with 1000mg/kg of test ingredient, no adverse reaction was observed until the 12th hour when loss of scale and ragged fins were noted with weak opercular movement and mortality recorded by the 24th hour.

In Phase 2, in fish administered 1600mg/kg of test ingredient, no adverse reaction was observed; by the 12th hour, fin erosion and normal opercular movement was observed while in the 24th hour, fin erosion and weak opercular movement were recorded. In fish administered 2900mg/kg of test ingredient, in the first 6th hour and the 12th hour, no adverse reaction was observed and in the 24th hour, mild fin erosion and weak swimming was recorded. In fish administered 5000mg/kg of test ingredient, in the first 6th hour, no adverse reaction was observed; in the 12th hour, mild tail fin erosion and slow opercular movement was recorded and in the 24th hour, mild tail fin erosion, slow opercular movement and mortality were recorded.

Table 1: Behavioural responses of *O. niloticus* administered crude clove buds

Phase 1	**6th hour**	**12th hour**	**24th hour**
10 mg/kg	A1	B1, C1	A2, C1, M
100 mg/kg	A1	B1, C1	B2, C2, M
1000 mg/kg	A1	C1	A2, C1, M
Phase 2			
1600 mg/kg	A2, B2	D1	D1
2900 mg/kg	A1	C2, B2	C2, B2
5000 mg/kg	A2	D2, A2, C1	D2, A2, C2

Table 2: Behavioural responses of *O. niloticus* administered clove buds aqueous extract

Phase 1	**6th hour**	**12th hour**	**24th hour**
10 mg/kg	A1	C1, B2	C1, B2
100 mg/kg	A1	C1, B2	C1, B2, M
1000 mg/kg	A1	D1, C1	D1, C1, B2, M
Phase 2			
1600 mg/kg	A1	C1	C1, B2
2900 mg/kg	A1	A1	C1, A2
5000 mg/kg	A1	C1, B2	C1, B2, M

A1: no adverse reaction/swimming

A2: weak swimming/ abnormal swimming

B1: normal opercular movement

B2: laboured breathing/opercular movement

C1: mild fin erosion/ragged fins

C2: pronounced fin erosion

D1: mild scale loss

D2: pronounced scale loss

M: mortality

Calculated LD_{50} value for crude and aqueous extract of clove buds

The calculated LD_{50} for crude clove buds was 223.61mg/kg while 538.52mg/kg was the calculated LD_{50} for clove aqueous extract.

DISCUSSION

Behavioural responses such as gasping for air, erratic or lethargic swimming, and even death have been reported in fish exposed to certain plant extracts (Zannatul *et al*., 2018; Ali, 2013). Fin erosion and loss of scale have also been reported. Orji *et al*. (2014) reported distress responses such as gulping of air, rapid opercula movement and erratic swimming within 15 minutes post exposure to aqueous extract of *Psychotria microphylla*. It was also noted that these responses were more pronounced with increasing concentrations. Ajani and Ayoola (2010) and Sultana *et al*. (2021) also reported dose dependent behavioural responses in fish administered herbal products. These reports are similar to what was observed in this study when crude and aqueous extract of clove were administered to *O. niloticus*. However, in a study by Afanyibo *et al*. (2019), clove did not exert any toxicity or stress responses in shrimp larvae when administered in vitro. The reason for this variation could be due to the type of extract used, concentration of extract and species used for the studies.

In the present study, doses above 10mg/kg caused mortality in the first 24 hours when crude clove was administered to *O. niloticus*. However, mortality was observed when doses of clove aqueous extract administered were above 10mg/kg. This report is not in agreement with the findings of Isaac *et al*. (2015) and Saeed *et al*. (2017) who reported that doses between 0.5-2.5g/kg of clovinol, a compound extracted from clove, did not induce mortality or abnormal responses. Humbal *et al*. (2019) in another study also noted no mortality in rats fed clove oil at doses between 50-200mg.kg for 28 days.

Although clove is considered safe for consumption by Food and Drug Administration, however, there are emerging reports on its possible toxicity. Tanko *et al*. (2008) reported LD_{50} of 567.7mg/kg in rats administered ethanolic extract of clove. In another study by Agbaje *et al*. (2009), LD_{50} values of 263mg/kg and 2500mg/kg were recorded in rats administered aqueous extract of clove intraperitoneally and orally, respectively. In the present study, LD_{50} values of 223.6mg/kg and 538.52mg/kg were obtained for clove crude and aqueous extract respectively. These values were within the values reported in previous studies. According to Hodge and Sterner (2005), these values are considered moderately toxic.

CONCLUSION

The study revealed that low doses (below 100mg/kg) of clove caused behavioural responses that can be attributed to toxic effect of the plant. Although the calculated median lethal doses for the crude and aqueous extract fall within moderate toxicity range, it should however be used cautiously. In addition, sub-lethal assessments of clove should be determined to ascertain its safety on long term administration in *O. niloticus*.

REFERENCES

Afanyibo, Y.G., Esseh, K., Idoh, K., Koudouvo, K., Agbonon, A. and Gbeassor, M. (2019). Toxicity and antioxidant activity of *Syzygium aromaticum*, *Mondia whitei*, *Carissa spinarum* and *Caesalpinia bonduc*. *Journal of Phytopharmacology* 8**(3):**124-128.

Agbaje, E.O., Adeneye, A. A. and Daramola, A. O. (2009). Biochemical and toxicological studies of aqueous extract of *Syzigium aromaticum* (l.) merr. & perry (myrtaceae) in rodents *African Journal of Traditional and Complementary and Alternative Medicines* **6(3):** 241 – 254

Ajani, E.K. and Ayoola, S.O. (2010). Acute toxicity of piscicidal plant extracts *(Adenia* *cissampeloides*) on Tilapia *(Sarotherodon galidaeus)* juveniles. *Iranica Journal of Energy and Environment* **1(3):**246-254.

Ali, M. K. (2013). Toxicity and behavioral response of *Heteropneustes fossilis* (Bloch) and *Oreochromis niloticus* (Linn.) exposed to *Polygonum hydropiper* (L.), *Lantana camara* (L.) and *Datura metel* (L.) leaf extracts. MS thesis, Department of Zoology, University of Chittagong., 176 pp.

Allemang, A., De Abrew, K.N., Shan, Y.K., Krailler, J.M. and Pfuhler, S. A (2021). Comparison of classical and 21st century genotoxicity tools: A proof of concept study of 18 chemicals comparing in vitro micronucleus, ToxTracker and genomics-based methods (TGx-DDI, whole genome clustering and connectivity mapping). *Environmental and Molecular Mutagenesis* **62:**92–107.

Antache, A., Cristea, V., Dediu, L., Grecu, L., Docan, A., Vasilean, I., Mocanu, M. and Şt. Petrea, M. (2013). The influence of some phytobiotics on growth performance of *Oreochromis niloticus* reared in an Intensive Recirculating Aquaculture System. *Lucrări Ştiinţifice-Seria Zootehnie;* **60:** 204-208

Batiha, G. E. S., Beshbishy, A. A., Tayebwa, D. S., Shaheen, M. H., Yokoyama, N. and Igarashi, I. (2018). Inhibitory effects of *Uncaria tomentosa* bark, *Myrtus communis* roots, *Origanum vulgare* leaves and *Cuminum cyminum* seeds extracts against the growth of Babesia and Theileria in vitro. *Japanese Journal of Veterinary Research Parasitology* **17:** 1–13

Beshbishy, A. M., Batiha, G. E. S., Adeyemi, O. S., Yokoyama, N. and Igarashi, I. (2019). Inhibitory effects of methanolic *Olea europaea* and acetonic *Acacia laeta* on the growth of Babesia and Theileria. *Asian Pacific Journal of Tropical Medicine* **12:** 425–434.

Humbal, B.R., Sadariya, K.A., Prajapati, J.A., Bhavsar, S.K. and Thaker, A.M. (2019). Safety evaluation of *Syzygium aromaticum* oil in male and female wistar rats. *Journal of Pharmacognosy and Phytochemistry* **8(4):** 3027-3032

Hodge, A. and Sterner, B. (2005). *Toxicity Classes.* **In**: Canadian Center for Occupational Health and Safety. http://www.ccohs.ca/oshanswers/chemicals/id50.html

Issac, A., Gopakumar, G., Kuttan, R., Maliakel, B. and Krishnakumar, I.M. (2015). Safety and anti-ulcerogenic activity of a novel polyphenol-rich extract of clove buds (*Syzygium aromaticum* L). *Food and Function* **6(3)**:842-852.

Jobi, X. and Kshetrimayum, K. (2020). Acute Toxicity of Leaf Extracts of Enydra fluctuans Lour in Zebrafish (*Danio rerio Hamilton*). *Hindawi Scientifica;* Article ID 3965376, 6 pp https://doi.org/10.1155/2020/3965376

Kouadio, J.H., Bleyere, M.N., Kone, M. and Dano, S.D. (2014). Acute and Sub-Acute Toxicity of Aqueous Extract of *Nauclea latifolia* in Swiss Mice and in OFA Rats. *Tropical Journal of Pharmaceutical Research* **13 (1):** 109-115

Kirkland, D., Kasper, P., Martus, H.J., Müller, L., van Benthem, J., Madia, F. and Corvi, R. (2016). Updated recommended lists of genotoxic and non-genotoxic chemicals for assessment of the performance of new or improved genotoxicity tests. *Mutation. Research:Genetic Toxicology and Environmental Mutagenesis* **795:**7–30.

Li, H.H., Yauk, C.L., Chen, R., Hyduke, D.R., Williams, A., Frötschl, R., Ellinger-Ziegelbauer, H., Pettit, S., Aubrecht, J. and Fornace Jr, A.J. (2019). TGx-DDI, a transcriptomic biomarker for genotoxicity hazard assessment of pharmaceuticals and environmental chemicals. *Frontiers in Big Data* **2:** 36.

Lorke, D. (1983). A new approach to practical acute toxicity testing. *Archives of Toxicology* **54:** 275–87.

Mishra, A., Sharma, A., Kumar, S., Saxena, A., Pandey, A. (2013). *Bauhinia variegata* leaf Extracts Exhibit Considerable Antibacterial, Antioxidant, And Anticancer Activities. *BioMed Research International* 2013:915436 https://doi:10.1155/2013/915436.

Mounanga, B. M., Mewono, L. and Angone, S. A. (2015). Toxicity studies of medicinal plants used in sub-Saharan Africa. *Journal of Ethnopharmacology*, 1–10. https://doi.org/10.1016/j.jep.2015.06.005

Murugan, P., Salim, A., Chenthamara, D., Robert, B. and Subramaniam, S. (2021). Therapeutic and pharmacological efficacy of selective Indian medicinal plants – A review. *Phytomedicine Plus* 1-31 https://doi:10.1016/J.PHYPLU.2021.100029

Ody, P. (2017). *The Complete Medicinal Herbal: A Practical Guide to the Healing Properties of Herbs*. Skyhorse Publishing Inc.: New York, NY, USA. 1–271pp

Obaroh, I. O. and Nzeh, G. C. (2013). Antifertility Effect of Some Plant Leaf Extracts on the Prolific Breeding of *Oreochromis niloticus. Academic Journal of Interdisciplinary Studies* **2(12):** 87-94

Ojetayo, T. A., Durojaiye, A.F., Bamidele, N. A., Ibitunde, O. R., and Sofowote O. A., (2022). Phytochemical constituents of *Cnestis ferruginea* and its toxicity in fish. *Jurnal Perikanan Universitas Gadjah Mada* **23 (2):** 47-54.

Olaniyi, C. O., Atoyebi, M. O., Obafunmiso, H. T. and Salaam, K. A. (2020). Effect of ginger (*Zingiber officinale*) in the nutrition of African catfish-A cholesterol reducer and fertility enhancer. *International Journal of Aquaculture and Fishery Sciences* **6(2):** 021-028.

Olatunbosun, L. O., Eltahir, A. G. K. and Atunwa, S. A. (2018). Safety and toxicity of aqueous leaf extracts of *Camellia sinensis, Parquetina nigrescens* and *Telfairia occidentalis* in mice. *African Journal of Pharmacy and Pharmacology* **12(18)**:208–220

Ruddaraju, L.K., Pammi, S.V.N., Guntuku, G.S., Padavala, V.S. and Kolapalli, V.R.M. (2020). A Review on Anti-Bacterials to Combat Resistance: From Ancient Era of Plants and Metals to Present and Future Perspectives of Green Nano Technological Combinations. *Asian Journal of Pharmaceutical Sciences* **15:**42–59.

Saeed, T.A., Osman, O.A., Amin, A.E. and El Badwi, S.M. (2017). Safety Assessment and Potential Anti-Inflammatory Effect of Ethanolic Extract of *Syzygium aromaticum* in Albino Rats. *Advances in Bioscience and Biotechnology* **8(11):**411-420.

Sultana, S., Nasiruddin, M. and Azadi, M.A. (2021). Piscicidal action and behavioral responses of Cichlid fish Tilapia, *Oreochromis niloticus* (Linn) exposed to three indigenous plant seed extracts. *Egyptian Journal of Aquatic Biology and Fisheries* **25(1):** 749-760

Schultz, F., Anywar, G., Wack, B., Quave, C. L. and Garbe, L.A. (2020). Ethnobotanical study of selected medicinal plants traditionally used in the rural Greater Mpigi region of Uganda. *Journal of Ethnopharmacology* **256:**112742. doi:10. 1016/j.jep.2020.112742

Sreedevi, P. and Vijayalakshmi, K. (2018). Acute oral toxicity study of ethanolic extract of *Punica granatum (l.)* leaves in zebra fish (*Danio rerio*). *World Journal of Pharmaceutical Research* **7(9)**:1058-1071

Tanko, Y., Mohammed, A., Okasha, M., Umah, A. and Magaji, R. (2008). Anti-nociceptive and anti-inflammatory activities of ethanol extract of *Syzygium aromaticum* flower bud in wistar rats and mice. *African Journal of Traditional and Complementary and Alternative Medicines* **5:**209–212.

Zannatul, F., Shakil Rana, K.M. and Ahsan Bin Habib, M. (2018). Piscicidal effects of plant seed extracts on predatory fish, *Channa punctatus* (Teleostei: Channidae) reared in aquarium journal of entomology and zoology *Journal of Entomology and Zoology Studies* **6(4):** 1232-1236

RELATIONSHIP BETWEEN SELECTED REPRODUCTIVE PARAMETERS OF *Bagrus bayad* IN KIRI RESERVOIR SHEL LENG, ADAMAWA STATE, NIGERIA

[1]HABU, U., [2] P. VANDI AND *[3]A. CHUBADO
[1] Department of Integrated Science, School for Secondary Education Science Programmes, Federal College of Education, Yola, PMB 2042
[2] Department of Zoology, Modibbo Adama University of Technology, Yola, PMB 2076
[3] Department of Biology, School for Secondary Education Science Programmes, Federal College of Education, Yola, PMB 2042
***** Correspondence Email: amchubado@fceyola.edu.ng

ABSTRACT
The study is aimed at investigating the relationship between maturity stages, fecundity, length-weight relationship and condition factor of Bagrus bayad. A total of 282 samples of B. bayad were collected over a period of 6 months and the data collected from its reproductive analysis were subjected to one-way analysis of variance (ANOVA), descriptive statistic, regression analysis, graph (bar chart) mean and standard deviation were used for analyzing and presenting the data for analysis. Result from the data analysis showed the b value for male = 1.996 which is less than 3.0, hence the male fish showed a negative allometric growth pattern. While that of the female showed that the b value was 3.297 which is positive allometric growth pattern and the combined sexes analysis shows that b= 2.330, which indicated a negative allometric growth pattern. The condition factors showed that the Male has K = 2.893, Female has K = 3.122 and the Combined Sexes Condition factor is K = 3.002. Male and female gonad maturing stages is III and IV. Stage I II and VI, no fecundity for these stages and mean total fecundity ranges from 44135.18 – 90908.25. However, the increase in fecundity is related with the increase in condition factor,

Keywords: Species, Aquatic, Environmental, Quantitative, Parameter, Reproductive

INTRODUCTION

Reproduction in fishes is one of the fundamental biological processes that enables survival and continuity of species in the aquatic environment (Yem, 2014). Maturity in fishes is very much governed by age, the type and quantity of food and certain environmental conditions. On attaining the proper age, the gonads start maturing gradually with the advent of breeding season. The gonadal development depends on several external factors in addition to the internal pituitary and gonadal (hormone) secretions (Gubta and Gubta, 2006). Fecundity is influenced by the fish size, kind of species, season and reproductive behavior. Marked differences in fecundity among fish often reflected different reproductive strategies (Murua and Saborido-Rey, 2003). The knowledge about these parameters is necessary for the determination of reproductive potential of fish populations and monitoring of changes in biological features of fish stock (Ahmad *et al.*, 2021). According to Wooton (1992), the volume of eggs produce depends upon the space available in the body cavity to accommodate the eggs before spawning. He also observed that in fishes generally large body size does not mean production of large size eggs; so, fecundity increases with increase in body size or body cavity. Length-weight gives information on the condition and the growth pattern of fish (Olurin and Adenibigbe, 2006). Length and weight measurement in conjunction with age data can give information on the stock composition, age at maturity, life span, mortality, growth and reproduction (Fafioye and Oluajo, 2005).Anderson and Neumann, (1996) ascertain that Condition factor refer to length weight data of population, or the ratio of length to the weight of fish which are the basic parameter for any monitoring study of fishes, since it provides important information concerning the structure and function of populations. Condition factor gives a picture of the general wellbeing of fish (Abubakar, 2006). The combination of the biological parameters of *B. bayad* considered in this study is important. Moreover, understanding the reproductive biology of *B. bayad* will aid the proper management strategies to sustain this valuable fish species. This rationale underpins the justification of this study.

MATERIALS AND METHODS

Study Area

The study area is Kiri reservoir in Shelleng Local Government Area of Adamawa State, Northeastern Nigeria. Kiri reservoir is a manmade lake from river Gongola and lies between 9^0 40.47" N, 12^0 0015" E. The reservoir has a total capacity of 615 million M^3. It is 1.2km long.

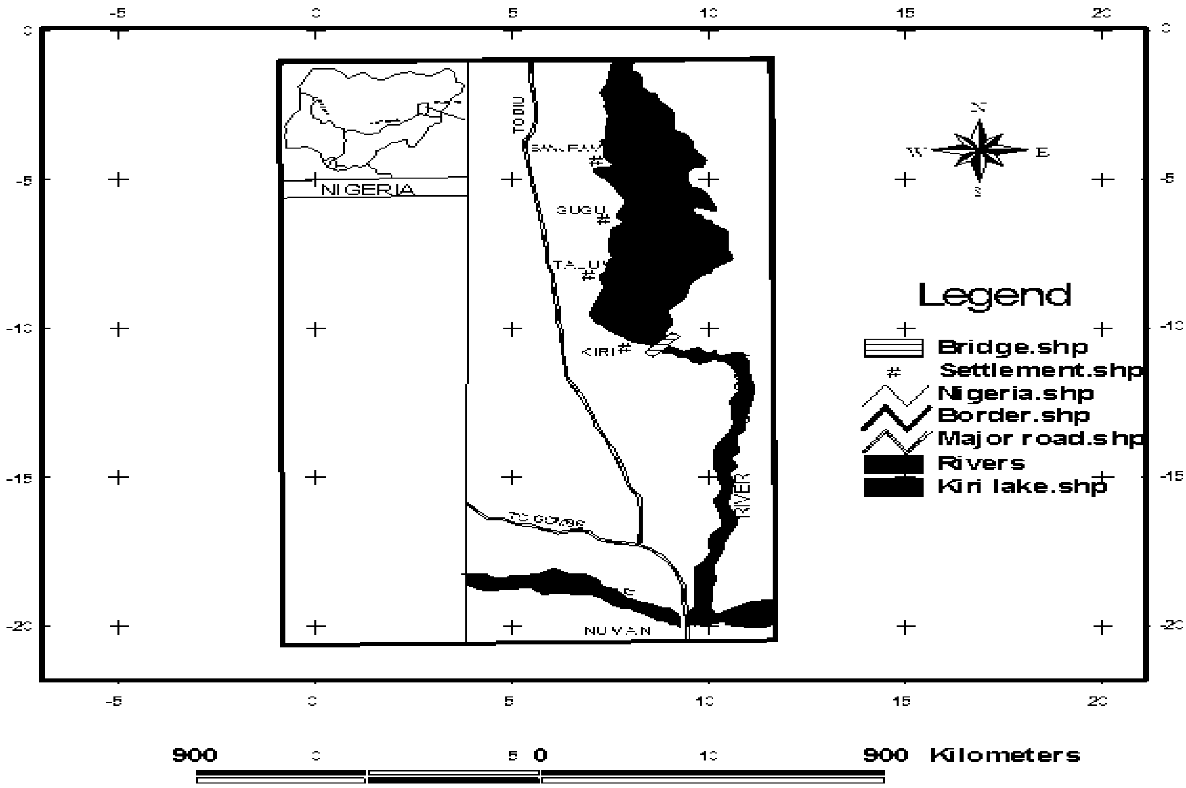

Figure 1: Map of Nigeria Showing the Location of Adamawa state, Kiri Town and Kiri Reservoir (Source: Google, 2016)

The reservoir was created from the damming of River Gongola, which was constructed in 1982, aimed at providing irrigation for Savannah Sugar Company (Institute of Civil Engineers, 1990). The host town Kiri is a River side resort with a unique feature and scenic of savannah landscape supplemented by the famous River Gongola with extensive Fadama flood plain. Kiri has a tropical savannah climate with two clear marked seasons of wet from April to October and dry from November to March.

Sample Collection

A total of 282 individuals of *Bagrus bayad* were randomly sampled monthly for 6 months and usually in the morning between 8:00am to 10:00am, and in the evening between 3:00pm and 5:30pm. A total of 47 males and female *B. bayad* samples were collected from the reservoir each month. The sample specimen was preserved with ice in a cooler and conveyed to laboratory where analysis for gonad maturity stages, length-weight measurement, fecundity and condition factor, were done. The duration for the study was 6 months from November 2016 to April, 2017. The fish used for the study were obtained from fishermen operating along kiri reservoir. The fishermen used various fishing gears ranging from hand nets, cast nets and gill nets of various standard mesh sizes (20.2, 25.4, and 30.5mm) as well as canoe and calabash were used as fishing craft. The Total Length (cm) of each fish was taken using a measuring ruler to the nearest 0.1 cm. Standard Length (cm) for each fish was taken to the nearest 0.1 cm. The total body weight in grams was measured for each fish sample to the nearest 0.01 g using a top loading Mettler balance (Mettler Toledo-ML204T). The sex of each fish sample was determined by visual observation of genitals.

Determination for Maturity Stages

Following Abbas (1982) techniques, the maturity stages of the ovaries and testis were identified and distinguished as follows: -

i. Stages I (Immature): Gonads are small, ovary is transparent, and eggs are small and cannot be detected by the naked eye. Testis is thread like.
ii. Stage II (Resting stage): Gonads are still small and extend along a ½ the length of the abdominal cavity. The ovary is still transparent and not thick. The eggs still cannot be distinguished with naked eye. Testis still without well define side lobes.
iii. Stage III (Maturation): The gonad begins to develop and extend along ¾ of the abdominal cavity length, ovary is yellowish. Eggs are distinguished to naked eye; Testis start to have side lobes.
iv. Stage IV (Maturity): Sexual products are clear the gonads nearly extend along the whole length of the abdominal cavity and reach their maximum weight. Ovaries are orange but the eggs still not extruded while tests lobes are clear, finger like and full of sperms.
v. Stage V (reproduction): Ovaries are voluminous with large viable eggs which could be seen through the thin ovarian wall. Testis is whitish in colour with stout lobes which are distended with sperms.
vi. Stage VI (Spent): The ovary is flaccid, reddish black in colour and much reduced in size, the testis is yellowish, white in colour, soft, empty and fleshy in its appearance.

Determination for Length-Weight Relationship

The length – weight relationship was determined using the conventional formula described by Le-Cren (1951).

$W = aL^b$

The equation and the data were transformed to logarithm before the determinations were done. The equation was therefore transformed into

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

Where:

W = Weight of fish in grams

L = Standard length of fish in cm

a = a constant

b = an exponent

Determination for Condition Factor

The condition factor "K" was determined for individual fish using conventional formula described by Worthington and Richardo (1931). The ratio of length to the weight of the fish was determined by the formula:

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

Where

K = condition factor

W= weight in grams

L = standard length in centimeters

Determination for Fecundity

Fecundity was determined as described in Gravimetric methods by Khanna and Singh (2003). Matured ovaries were carefully removed (after making an incision from the vent to the lower jaw to expose the visceral organs of the fish) and preserved in 10% formalin in Petri dish. The weight of ovaries was determined and 3 samples of 100mg each were taken at random from interior, middle and posterior, and were counted under a binocular microscope. Fecundity was determined by the formula;

$$F = \frac{S \times OW}{100}$$

Where;

F = Fecundity

S = Average number of eggs from 3 samples 100mg each

OW = Total weight of Ova

Statistical Analyses

One-way analysis of variance (ANOVA), descriptive statistic, regression analysis, graph (bar chart) mean and standard deviation were used in presenting and analysing the data. Pearson Product Moment Correlation was used to determine the relationship between data on GSI and fecundity of *B. bayad* in the study area. $P< 0.05$ was set up as the confidence level.

RESULTS

Length-Weight Relationship of *Bagrus bayad*

The result as presented in Table 1 showed that b value = 1.996 for the male which is less than 3.0, hence the male fish showed a negative allometry growth. A correlation value $r^2 = 0.545$, N=162; $p<0.05$ is significant, while the female b value is 3.2971, which is a positive allometric, with very high and significant r value, $r^2 = 0.833$, N=120; $p<0.05$**,** however combined sexes analysis shows that b=2.330 which indicated a negative allometric growth and the r^2= 0.622, N=282; p<0.05 is a significant correlation.

Table 1: Length-Weight relationship, Growth Pattern and Mean Condition factor of *Bagrus bayad*

Sex	L-W relationship equation	Growth pattern (b-value)	r^2	Mean K value
Male	LogW=Log5.795-1.996LogL	1.996 (Negative Allometric)	0.545	2.893
Female	LogW=Log10.87– 3.297Log L	3.297 (Positive Allometric)	0.822	3.112
Combined	LogW=Log7.079+ 2.330LogL	2.330 (Negative Allometric)	0.622	3.002

Gonad Maturity of Male and Female *Bagrus bayad*

The Male gonad maturity showed stages I-V while the females were from stages I –VI as presented on Figure 1. More females were in stages I, III and V while more Males in Stages II and IV. Majority of the *B.bayad* were in stages III with 30.0% of Males were and 32.8% of the Females.

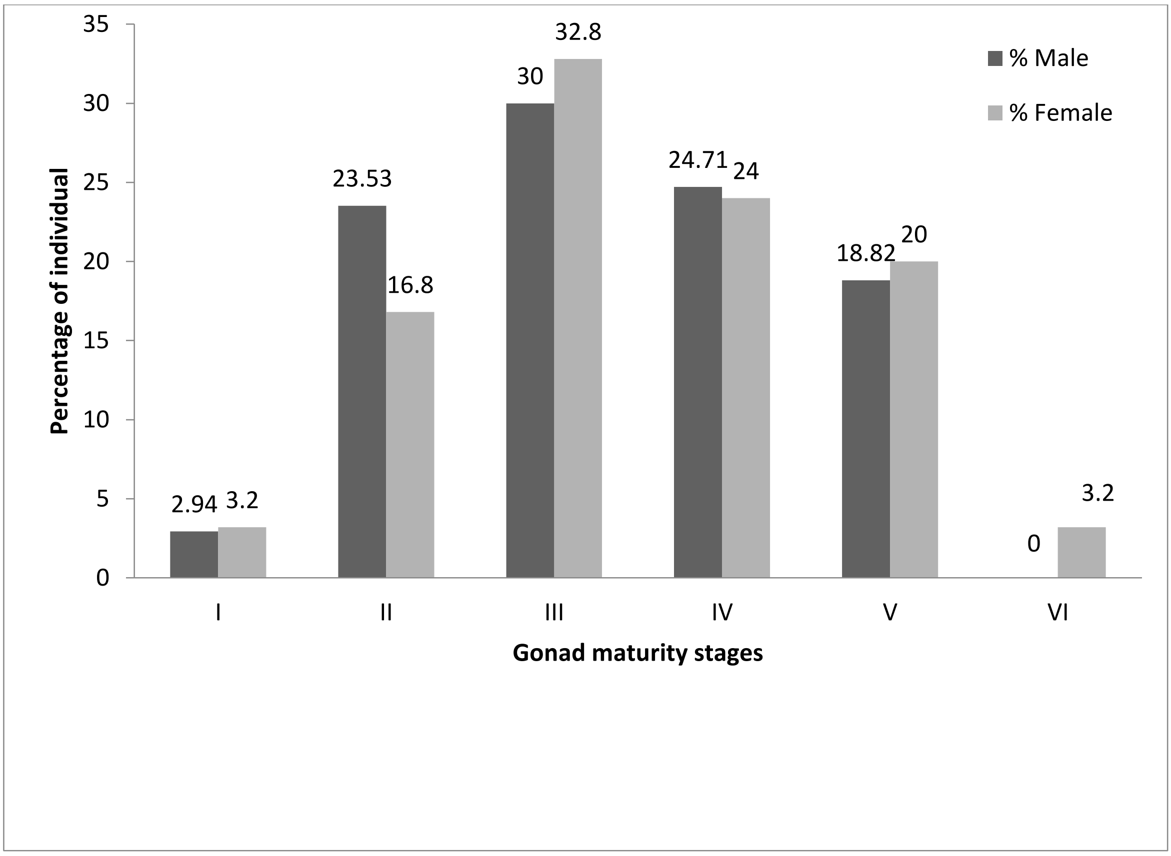

Figure 1: Gonad maturity comparison between the male and female *Bagrus bayad* from Kiri Reservoir

Gonad Maturity, Length-Weight and Condition factor of Male *Bagrus bayad*

The relationship between the gonad maturity, length, weight, and condition factor of Male *B. bayad* in Kiri reservoir is presented in Table 2. The Condition factor of fish improves from Stage I to Stage V. The stages I and II were found immature while III and IV were maturing and stage V matured. The Mean weight is from 0.282kg to 3.4kg for stage I and V respectively while the lengths were 19.8 cm and 66.48cm for stages I and V respectively.

Table 2: Relationship between Gonad maturity stages with length – weight and condition factor of males

#	Mean weight(kg)	Mean length (cm)	Condition factor	Remark
I	0.282	19.80	1.116	Immature
II	0.647	32.08	1.621	Immature
III	1.374	45.94	2.456	Maturing
IV	2.505	57.50	3.620	Maturing
V	3.400	66.42	4.484	Mature

Gonad Maturity, Length-Weight and Condition factor of Female *Bagrus bayad*

The relationship between the gonad maturities, length, weight, and condition factor of Female *B. bayad* in Kiri reservoir is presented in Table 3. The Condition factor of fish improves from Stage I to Stage VI. The stages I and II were found immature while III and IV were maturity, stage V matured and stage VI were spent fish. The weight ranged from 0.323kg to 3.2kg for stage I to VI respectively while the lengths ranged between 23.03 cm and 62.5cm for stages I to VI respectively.

Table 3: Relationship between gonad maturity stages with length – weight and condition factor of females

Gonad stages	Mean weight (kg)	Mean length (cm)	Condition factor	Remark
I	0.323	23.03	1.171	Immature
II	0.705	34.37	1.589	Immature
III	1.560	48.24	2.694	Maturing
IV	2.615	60.22	3.736	Maturing
V	3.328	65.42	4.416	Matured
VI	3.200	62.50	4.592	Spent

Relationship between Fecundity and Condition factors of Female *Bagrus bayad*

Stages I, II and VI were found with empty ovary hence no fecundity for these stages. The fecundity and Total Fecundity in stages III, IV and V increased with increase in Condition factor (Table 4)

Table 4: Relationship between Gonad maturity stages, fecundity and Condition factor in female

Gonad stages	Fecundity/g of ovary	Total Fecundity	Condition factor	Remark
I			1.171	Immature
II			1.589	Immature
III	1637.46	44135.18	2.694	Maturing
IV	1653.27	86207.32	3.736	Maturing
V	1666.75	90908.25	4.416	Matured
VI			4.592	Spent

DISCUSSION

The size and age of sexual maturity and sex ratio are fundamental biological parameters use in stock assessment and useful in management to calculate the reproductive potential of fish population (Wang *et al.*, 2003). In the present investigation on the maturity stages of *B. bayad* species, indicates that there is relationship between the length weight and maturity stages, it also reveals that female *B. bayad* has more length and weight at first maturity stage than the male *B. bayad.* During the period of this study it was observed that 30% of male reached the first maturity stage while 32.8% of female reached first maturity stage. This is evidence that more female of *Bagrus bayad* reached first maturity stage than the male with a sex ratio of 1:1.09, this is in agreement with the findings of Imam *et al*. (2011) who reported sex ratio of 1:1.04 for Male and Female *S. Schall* in Assiut. However, in Lake Nasser. The length-weight relationship of any fish is basically known to measure its growth pattern which is an important component of biological production (Fafioye and Oluajo 2005).

The growth pattern exhibited by *B. bayad* as presented in the results showed negative allometry for male and positive allometry for female. This pattern of growth has been earlier reported by Offem *et al*., (2008) who recorded mean b values of 3.206, and 2.040 in Cross River, which depicted negative and positive allometric growths. There was observed variation in the "b" value of the fish under study. It showed that the rate of increase in body length is not proportional to the rate of increase in body weight. The values obtained for the length-weight relationship showed that both sexes of *B. bayad* exhibited allometric growth pattern. This agrees with "b" value 2.911 and 2.794 recorded for *Clarias gariepinus* (African sharp tooth catfish) (King, 1996). Ogbe *et al*., (2006) reported positive allometric growth pattern for *B. bayad* from Lower Benue River. In a similar study, Ogbe and Ataguba, (2008) also reported an isometric growth pattern for *Malapterurus electricus* from Lower Benue River. The "b" value obtained for the species in this study were within the range (1.996-3.297), similar to what has been reported for Volta River Bagrids (Entsua-Mensah *et al.*, 1995). The assessment of fecundity is the corner stone of the reproductive biology, since it is not a stable character due to changes in environmental condition and species-specific factors (Khallaf and Authman, 1991). This study reveals that maturity stages of *B. bayad* ranges from III – V stages, with mean fecundity per gram of ovary ranges between 1637.46 – 1666.75 and mean total fecundity ranges from 44135.18 – 90908.25. However, the increase in fecundity is related with the increase in condition factor, as shown in the result of this study, which indicate that as the fish moves from stage III of gonad stage to IV or V its condition factor increases as a result of increase in length and weight of the fish, from stage I – V with mean weight of 0.323kg – 3.2kg respectively and mean length ranges from 23.03 – 62.5cm for stages I – V respectively. These are similar to findings of Tsadu, *et al*., (2014) who reported that *B. bayad* species do not reach reproductive stage until they are about 1kg and above in total body weight. The present result is in contrast with Abayomi and Arowomo, (1996) recorded 650,625 eggs for C. *Gariepinus* in Opa reservoir, Nigeria. However, variation in fecundity of individual's fish may be due to differential abundance of food. Nutritional resources are known to play critical roles in regulating variations in fecundity.

It was observed in the present study that mean condition factor for *B.bayad* were of values above 1.0 which indicated that fish species are doing well in the reservoir. The condition factor of the fish species in this study is favorably comparable with condition factors of different tropical fish species investigated and previously reported (Saliu, 2001 and Lizama*et al.*, 2002). The condition factors of male, female 2.893, 3.112 respectively and combined sexes was 3.002 of *B. bayad* in the present study is similar to what was reported by Lawal *et al*., (2010). The high condition factor is an indication of food availability and good water quality in the reservoir. A very high and significantly different Pearson Correlation, r^2= 0.833 between the male and female condition factors. The monthly variations in condition factors for female showed that the values were very low and some were negatively correlated such as January and March having r^2=-0.0740; p>0.05 N=120 and November and March r^2=-0.07405; p>0.05, N=162. The highest correlation r^2=0.345108; p>0.05, N=120 was recorded between the condition factor in the months of February and April while the lowest r^2=0.011576; p>0.05, N=120 was from January and April. On the other side, the correlation of the monthly mean condition factor of male *B. bayad* from Kiri reservoir indicated that four months showed negative correlations of r^2= -0.12431, r^2= -0.1874, r^2= -0.1479 and r^2= -0.00707 for December and February, November and April, January and April and March respectively. The highest Monthly mean correlation r^2=0.51993 was computed between November and December while the lowest r^2=0.001393 was from November and March. This type of variations agreed with the report of Ikongeh *et al*., (2012).

CONCLUSION

It was obvious based on the result obtained from the study that there was no significant relationship between the length and weight of the fish (*B.bayad*), hence growth pattern is negative allometric for male and positive allometric for the female. The gonad first maturing stage of the fish is stages III and IV, while stage V is matured, and there is a significant relationship between gonad maturity stages with length-weight. Fecundity increases with increase in condition factor of fish. However, condition factor of the fish in this study is favorably comparable with condition factors of any tropical fish.

REFERENCES

Abass, F.F. (1982). Studies on catfishes of Lake Nasser, biological studies on family Synontidae. M.Sc. Thesis, Assuit University, Egypt.

Abayomi, O. S. and Arowomo, G.A.O. (1996). Sex ration and fecundity of, *Clarias gariepinus* in Opa reservoir, Ile-Ife, Nigeria. proceedings of the Ann. Conf. of fisheries society of Nigeria (FISON) 122-130p.

Abubakar, K.A. (2006). A study of aspect of productivity and stock status of *Oreochromis niloticus and Clarias gariepinus* in Lake Geriyo, Yola Adamawa state Nigeria. PhD Thesis Federal University of Technology, Yola. 212 pp.

Ahmad, N. D., Abdulkarim, B. and Suleiman, M. (2021). Reproductive Biology of *Bagrus bayad* (Forskal, 1775) from Jibiya Dam of Katsina State, Nigeria, *Ind. J. Pure App.Biosci. 9*(4), 111-117. doi: http://dx.doi.org/10.18782/2582-2845.8735

Anderson, O.R. and Neumann, R.M. (1996). Length, Weight and Associated Structural Indices P. 447-482 in: Nielsen L. A and Johnson D. L. (Eds). Fisheries Techniques Bethesda American fisheries society 732p.

Entsua – mensah. O. A and Palomeres, M.I.D. (1995). Length – Weight relationship of fishes from tributaries of the volta River, Qhunu: part I analysis of pooled data sets *NAGA ICLARM – Quarterty*, 18 (1): 36-38

Fafioye, O.O, and Oluajo, O.A. (2005). Length-weight relationships of five fish species in Epe Lagoon, *Nigerian. African Journal of biotechnology,* 4(7): 749 – 751.

Gupta, S.K and, Gupta, P.C. (2010). General and applied ichthyology *(*fish and fisheries) for B.Sc. /B.FSc. M.Sc./M.F.Sc. and other courses in fishery Science. S. Chand and company PVT. LTD.

Haimovic, M. and Velasco, G. (2000). Length-Weight relationship of marine fish from southern Brazil. *The ICLARM Quaterly,* 23(1):14-16.

Ikongbeh, O.A., Ogbe, F.G. and Solomon, S.G. (2012). In Press. *The growth pattern of Chrysichtbyes nigrodigitatus* from Lake Akata, Benue State, Nigeria.

Imam, A.A., Mekkawy. and Arafa, A.H. (2011). Some reproductive parameters of *Synodontis Schall* (Bloch and Schneider, 1801) from the River Nile Egypt. *Journal of fisheries and aquatic science,* 6**:** 456-471.

Khallaf, E.A. and Authman, M. (1991). Growth and Mortalily of *Bagrus bayad* (Forskal) in Bahr Shebeen Canel. *Journal. Egypt. Ger. Society. Zoology.* 4: 87-109.

Kannah, S.S. and Singh, H.R. (2003). A *Textbook of Fish Biology and Fisheries.Narendra*. Publishing House Delhi-India.

Lawal, M.O., Sangoleye, O.J. and Seriki, B.M. (2010). Morphometry and diet of *Chrysichtbyes nigrodigitatus* (Lacepede) in Epe Lagoon.Nigeria. *African Journal of Biotechnology* 9*(*46*)*: 7955 – 7960.

Le-Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the Perch. PercaFluvialitis. *Journal Amin. Ecology.*20:201-219.

Lizama, M.D., Los, A.P. and Ambroso, A. (2002). Condition factor in nine species of fish of the Claracidae family in the upper Parana River floodplain, Brazil. *Brazilian Journal of biology,* 62(1): 113 – 124.

Murua, H. and Saborido-Rey, F. (2003). Female reproductive strategies of marine fish and their classification in North Atlantic. *Journal of Northwest Atlantic Fisheries Science*, *33*, 23-31.

Offem, B.O., Samson, A.Y. and Omoniyi, I.T. (2008). Diet, saize and the reproductive biology of the silver catfish chryshthysnigrogiditatus (siluformes: Bagridae) in the Cross-River Nigeria. *International journal of tropical biology,* 56 (4):1785-1799.

Ogbe, F.G., Obande, R.A. and Okayi, R.G. (2006). Age, Growth and mortality of *Bagrus bayad*, (Macropetrus, 1935). From Lower Benue River, Nigeria. *Biological and Environmental Science Journal for the*

Tropics, ***3***: 103-109.

Ogbe, F.G., Kappo, A. and Cheikyula, J.O. (2003). Age and Growth Studies of Auchenoglanis occidentalis (Valenciennes, 1775) from Lower Benue River using Bhattacharya Method. *The Zoologist*, 2(2): 36 – 45.

Olurin, K.B. and Aderibigbe, O.A. (2006). Length-weight relationship & condition factor of pond reared Juvenile O. Niloticus. *World Journal of Zoology*, 1(2): 82-85

Samuel, G. E. (1998). Structural adjustment agrarian change and rural ethnicity in Nigeria. *Nordic African institute*. Pp. 87 – 89 ISBN 91 – 7106 – 426 – 5.

Sani, R, B.K., Gupta, U.K., Sarkar, A., Pandey, V.K., D., and Lakra, W.S. (2010). Length-weight relationships of 14 Indian freshwater fish species from the Betwa (Yamuna River tributary) and Gomti (Ganga River tributary). *Journal of Applied ichthyology.* 26: 456- 45

Saliu, J.K (2001). Observation on the condition factor of Brycinus nurse (Pisces: Cypriniformes, Characidae) from Asa Reservior, Ilorin, Nigeria. *Tropical Freshwater Biology*, 10: 9-17. 459.

Srivastava, P. and Shipra, C. (2013). Length–weight relationships (LWR) of threatened Asian catfish, *Clarias batrachus* under poor availability in natural conditions from Unnao, Uttar Pradesh, *India1 Advances in Applied Science Research*, 4(6): 138-141.

Tsadu, S.K.., Lamai, S.L, Yisa, T.A. and Ibrahim, S.U. (2014) Gonad Development and Histology in *Bagrus bayad* cultured in outdoor earthen ponds *Journal of Biological and Chemical Research* 52-65.

Wang, S.P., Sun. C.L. and Yeh, S.Z. (2003). Sex ratios and sexual maturity of swordfish (Xiphiasgladius L.) in the waters of Taiwan. *Zoology Stud.*, 42**:**529-539.

Warthington, B. E, and Richardo, C.K. (1931). Scientific Result of the Camdridge Expenditure Expenditure to the East Africa Lakes No. 15 the fishes of Lake Rud off and Lake Breringo. *Journal of Lin.Zoology*.267:353-389.

Wootton, R. J. (1992). *Fish ecology: Tertiary level biology*. Chapman and Hall, New York, U.S.A. 132-140p.

Yem, I.Y. (2014). Studies on the biology of silver catfish (*Chrysichthys nigrodigitatus*L acèpède 1803) in Jebba lake, Nigeria. *A Published Ph.D Thesis*, Ahmadu Bello University, Zaria.

TRENDS IN FISHERIES, AQUACULTURE AND CONSUMPTION IN NIGERIA

OGUNBADEJO H. K.
Nigerian Institute for Oceanography and Marine Research, Lagos.
*Corresponding Author: ogunbadedejohk@yahoo.com +234 8023911896

ABSTRACT
The production and consumption trends of fish in Nigeria were examined in this study. The study used secondary data from the Food and Agriculture Organization Statistics (FAOSTAT) and World Bank statistics for the period of 1971–2021. The data was analyzed using the growth and Auto-Regressive Integrated Moving Average (ARIMA) models. The study's findings showed that the annual average growth rate of total fish production from 1971 to 2021 was 3.01%, aquaculture was 8.84%, capture 2.444% while imports stood at 4.3%. The annual average growth rate for the years 2022 to 2025 was forecasted to be 2.9% for total fish production, 4.7% for aquaculture, 2.5% for capture and 3.8% for imports. The study revealed a significant degree of concentration in the importation of foreign fishing resources. The Nigerian fish importers have implemented backward integration into commercial aquaculture in an effort to lower the country's import costs. Fish import growth rate accelerated, however, fish production growth rate slowed down. To achieve a balanced trade of Nigerian fisheries, the report recommends allocating additional resources to the export sector of the country's fisheries and implementing counter-dumping regulations in the import sector.

Keywords: Fisheries performance; Time - series, Forecasting Models, global growth rate.

INTRODUCTION

Fish, mollusks, crustaceans, and aquatic plants can all be farmed through the process known as aquaculture. Aquaculture output that is intended for final harvest for human use is referred to as aquaculture production. Fisheries is a significant economic industry that employs over 8.6 million people directly and an additional 19.6 million indirectly, with women making up 70% of the workforce (Worldfish, 2021). At the moment, Nigeria produces just over 1 million metric tons of fish, leaving an annual import imbalance of over 800,000 metric tons (Worldfish, 2021). Although these industries are not the main agricultural operations in Nigeria, aquaculture and fishing are significant food additions (Amosu *et al.*, 2017). Nigeria is currently the second-largest fish producer in Africa, behind Egypt, the influence that aquaculture and fisheries has on the country's Gross Domestic Product (GDP) cannot be overlooked because they account for 1.09% of the country's agricultural GDP (NBS, 2020). Fish is a nutrient-rich food with a wide range of culinary and medicinal applications. The demand for fishery products has increased both nationally and internationally in recent years as more people have become aware of the health benefits of eating fish.

This tendency is anticipated to continue in the ensuing decades as well, according to the growing population and the unavoidable requirement to address the food problem. The development of fish-based companies requires an increase in fish production and progress in the fishing industry (Garcia and Rosenberg, 2010).

In spite of Nigeria's abundance of natural water resources, the freshwater ecosystems have not yet reached their full potential. Even while fish farming offers tremendous potential for boosting the country's economy, there are several obstacles standing in the way of its success. In order to encourage economic and scientific developments in the aquaculture and fishing industry, these challenges must be seriously addressed. These challenges include reducing the country's reliance on oil, diversifying the economy, addressing the lack of infrastructure, creating strong institutions, and enhancing governance, public financial management systems, as well as human development indicators (Federal Ministry of Finance, 2020).

A thorough examination of the current state of affairs and developmental tendencies can be used to anticipate the possibilities for fisheries and aquaculture in the future (Pauly *et al*, 2003). Therefore, this article focuses on examining these patterns to provide a thorough picture of the current situation of the aquaculture and fisheries industry in Nigeria. Doing so may aid researchers in proposing the most appropriate strategies for the sector's development. It will assist decision-makers and other interested parties in identifying intervention areas and developing suitable programs, plans, and policies for the growth of Nigeria's aquaculture and fisheries industry. It also makes an effort to highlight the pressing concerns surrounding the industries of fish production, marketing, and commerce.

MATERIALS AND METHODS

Study Area

The investigation was carried out in Nigeria, a sub-Saharan country on the Gulf of Guinea. Over 218.5

million people were reportedly living in Nigeria as of 2022 (World Data, 2022), which has a total land area of 923,770 km^2 (FAO, 2020b). Nigeria is bounded by the Gulf of Guinea to the south, Benin to the west, Niger to the north, Cameroon and Chad to the east, and longitudes 2° 49'E and 14° 37'E and latitudes 4° 16'N and 13° 52' North of the Equator.

There are 923,768 km^2 of land in all, and 37,934 km^2 make up the continental shelf. According to the FAO (2020b), its coastline is 853 km long and has a 210,900 km-long Exclusive Economic Zone. About 11,666,000 hectares are thought to be the total area and distribution of the main inland water system (lakes and rivers).

Data Sources

The investigation of the paper, which covered the years 1971 through 2021, utilised secondary data. Several sources, including the Federal Department of Fisheries (FDF), the Food and Agriculture Organization Statistics (FAOSTAT), and World Bank statistics, were used to compile the data.

Methods

Based on annual growth rates, the average annual growth rate shows how quickly an economy has changed on average throughout time. An annual growth rate's geometric mean is what we refer to as the average annual growth rate.

Determine the average yearly growth rate $= \frac{Yt}{Yt-1}$ ^ $1/(n-1) \times 100$ The global growth rate multiplied by $1/(n-1)$, where n is the number of years, equates to the average annual growth rate. A variety of techniques are employed to investigate time series data and projections. It can be divided into groups of theoretical models, a group of linear and non-linear models, partial equilibrium, and general equilibrium based on their typology.

Box-Jenkins 'Method

The study of the numerical time series to project trends using the ARIMA model one of the categories of models called ARIMA attempts to calculate each value of the series in relation to the values that came before it $y_t = {}_f(yt-1, yt-2\,yt, yt-n)$. A theoretical model is the name given to it. Box and Jenkins (1976) popularized and codified this group of models.

To be clear, autoregressive processes presume that each point may be anticipated by the weighted sum of a set of prior points plus a random error factor. The integration procedure presupposes that there is a constant difference between each point and the one before it. Moving average methods assume that each point is a combination of its own error and the errors of the points that came before it. In the class of statistical models used to examine and project time-series in agriculture and rural development, ARIMA is a potent tool. Numerous organizations (FAO, USAID, IITA, etc.). The fish production figures from 2022 to 2025 are forecast using the Auto-Regressive Integrated Moving Average (ARIMA,1,1,3) model, it is frequently used when analyzing projections in situations like these, with user interface of the E-Views 9.0 software.

RESULTS

Aquaculture production in Nigeria has increased by 8.84 percent a year over the past 52 years (in contrast to the global average of 8%), rising from just over 3993 metric tons in 1971 to about 275,845 metric tons in 2021 (Figure 1). Capture fish has increased from 241,303 in 1971 to 805,210 metrics tons in 2021 about 2.44% increase per year. Nigerian aquaculture mostly focuses on freshwater fish, with catfish species producing 64% of the nation's aquaculture in 2015. Catfish, typically grown in ponds and tanks, is the most farmed species in Nigeria, constituting about176,540.8 metric tons in 2021.

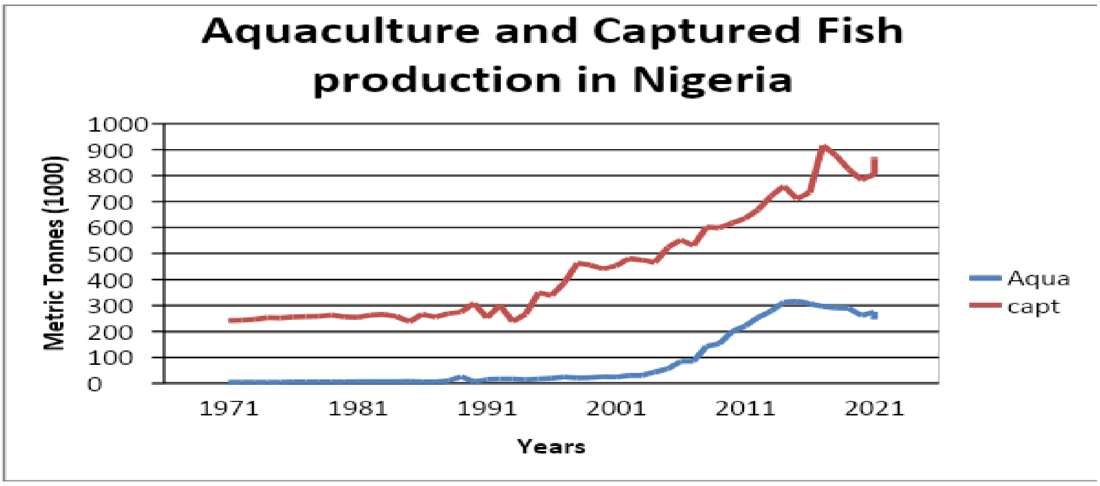

Fig 1: Trends of aquaculture and captured fish production in Nigeria 1971- 2025

The fish consumption increased yearly by3.31% from 1971 to 2021, and between 1980 and 2013, Nigeria's apparent total fish consumption increased by 55% due to an increase in fish output; the remaining 45% was covered by an increase in net fish imports (i.e., imports less exports). Between 2000 and 2011, the fish trade imbalance expanded from 350,000 metric tons to almost 2 million metric tons before dropping to 860,000 metric tons in 2013 (Figure 2) as a result of a sharp rise in local fish production. It was increased to about 1.07 million metric tons in 2014 and marginal increase to 1.08 metric tons in 2021.

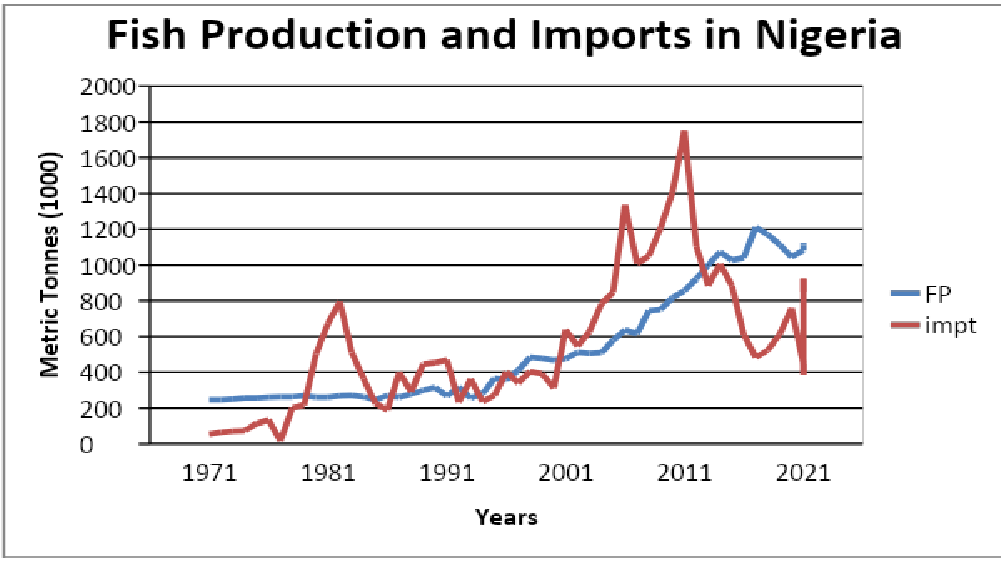

Fig 2: Trends of fish consumption in Nigeria 1971- 2025

Nigeria imported N265.4 billion worth of fish in 2021, up 41.5 percent from N187.6 billion in 2020. The country's fishing industry expanded by 3.33 percent in 2019, 0.26 percent in 2020, and only slightly (1.16 percent) in 2021 (Table 1). However, the decrease in imports allowed for an improvement in the fish self-sufficiency rate (Figure 4), which ranged from 26% to 70% of demand between 2012 and 2025.

Table 1: Fish Production and Consumption in Nigeria 1971 -2025

year	Fish production	Aquaculture	capture	imported	Consumption
1971	245296	3993	241303	54416	299712
1980	258633.3	5096.444	253536.9	155584.4	414217.8
1990	274011.7	8937.1	265074.6	435397.6	709409.3
2000	368659.8	19289.3	349370.5	342372.6	711032.4
2010	614834.5	85224.6	529609.9	945334.1	1560169
2011	856614	221128	635486	1749785	2606399
2012	922652	253898	668754	1106355	2029007
2013	1000061	278706	721355	885596	1885657
2014	1073059	313231	759828	1006263	2079322
2015	1027058	316727	710331	884723	1911781
2016	1041498	306767	734731	610648	1652146
2017	1212475	296191	916284	483047	1695522
2018	1169478	291323	878155	524024	1693502
2019	1114556	289543	825013	611978.6	1726535
2020	1044813	261711	783102	759625.2	1804438
2021	1080855	275645	805210	446941.3	1527796
Growth %	**3.01**	**8.84**	**2.44**	**4.3**	**3.31**
2022	1040363	199443.6	840919.9	732100.6	1772464
2023	1070731	208971.7	861759	768689.2	1839420
2024	1101984	218869.7	883114.5	807106.5	1909091
2025	1134150	229150.8	904999.3	847443.8	1981594
Growth %	**2.9189**	**4.7371**	**2.4781**	**4.9978**	**3.7876**

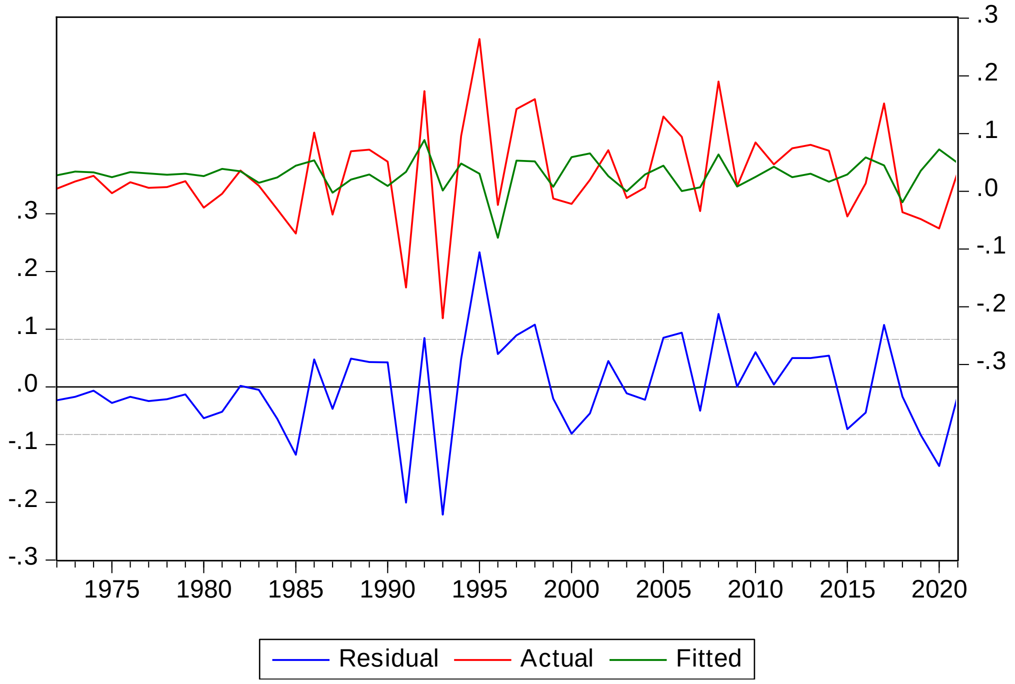

Figure 3: Actual series, fitted series and residual series of the DLFP sequence

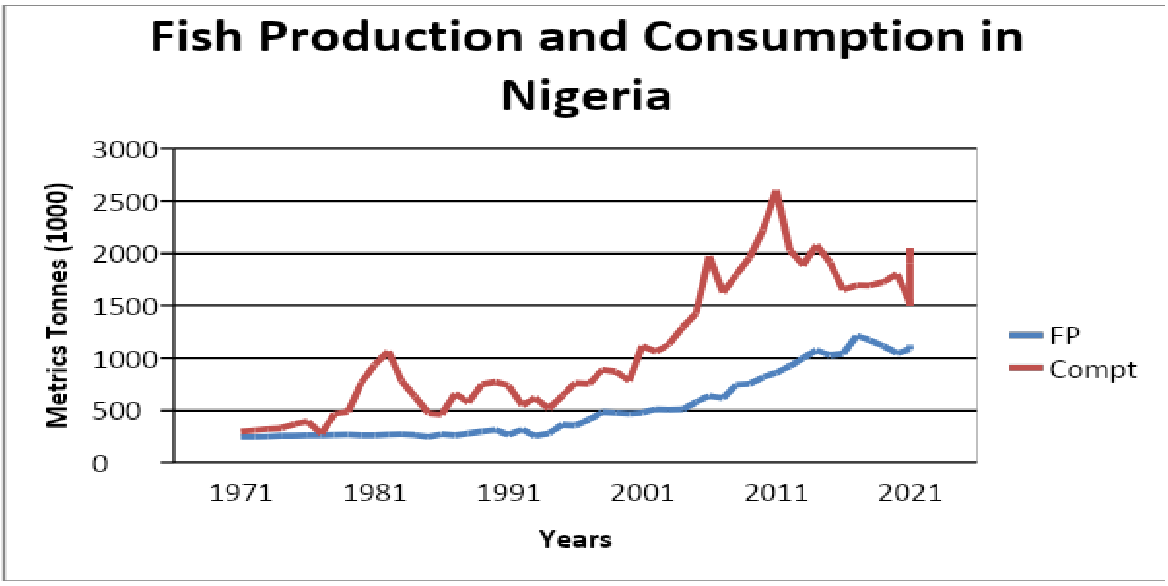

Fig 4: Fish Production and Consumption in Nigeria 1970 -2021

DISCUSSION

With an annual growth rate of 3.01 percent compared to the global increase of 3.3 percent, total fisheries and aquaculture production have increased significantly over the past five decades, rising from 245,296 metric tonnes (Live weight equivalent) in 1970 to an all-time high of about 1.08 million tonnes in 2020. After then, production fell in 2019 (a decrease of 4.9% from 2017), before rising by 3.3% to reach 1.08 million tonnes in 2021. The two-year standstill is largely attributable to a fall in captured fisheries, which fell by 6.4 percent in 2019 compared to their peak of 878,155 metric tonnes in 2018 and then by a further 2.4 percent in 2021.

The drop was caused by a number of elements, such as shifting pelagic species captures, national insecurity, and the effects of COVID-19 on the industry in 2020. Additionally, aquaculture production—the primary factor in the increase in total production since the late 1980s—has continued to rise, albeit at a slower rate in the last three years: -0.61% in 2018–2019, compared to a global average of 3.3%, -9.6% in 2019–2020, compared to a global average of 2.6%, and 5.52% in 2020–2021, as opposed to an average annual growth rate of 7.9% between 2010–2018 (FAO, 2020a).The only option that would result in a decrease in the expected actual pricing of low-value food fish is faster aquaculture expansion, albeit this scenario would also result in a considerable increase in the price of fishmeal (Christopher *et al*., 2020).

The impact of policy changes in Nigeria focused on electoral policies at the expense of economic development and various issues linked to Covid-19 in 2020 that not only impacted production for exports but also reduced availability of workers, supplies and inputs (including feed, and fingerlings and ice) while disrupting transportation and marketing, as well as sanitary measures are some of the causes of these lower growth rates in the fisheries sub-sectors (FAO,2020b).

Aquaculture's contribution to overall fisheries and aquaculture production has further expanded as it has developed more quickly than capture fisheries over the past two decades. A total of 1.08 million tonnes were produced in 2021, with capture fisheries contributing 74% (805,210 metric tonnes) and aquaculture contributing 36% (275,645 metric tonnes). This represents a significant shift from the aquaculture share of 4.6% in the 1970s, 23% in the 1980s, 23.6% in the 2010s, and 7.07% in the 2020s. Despite the expansion, the primary source of production remains the catch fisheries.

Fish demand in the country is 3.6 million metric tonnes, but total domestic production from all sources is only 1 080,855 metric tonnes annually, leaving a demand-supply gap of approximately 2.52 million metric tonnes in 2021. If the government does not make a concerted effort to increase domestic fish productivity, fish imports will continue to fill the gap between local supply and demand, sapping significant amounts of foreign currency (Subasinghe *et al*., 2021).

The predicting relative errors for fish production are 0.19% and 1.51%, respectively, for the years 2022 to 2025. Since the forecast are based on ARIMA model that has been fitted to the complete set of data, the root-mean-square error (RMSE) from the residuals is reduced as would be expected. It provides insightful information about how well our forecasting model is performing.

CONCLUSION

Nigeria has enormous potential for fisheries and aquaculture output. With its promising status and constantly changing development patterns, Nigeria's aquaculture and fisheries sector has improved satisfactorily in recent years, mostly because of initiatives like Nigerian National Fisheries Policy. The production situation is still in a precarious state because the relevant parties haven't fully investigated the enormous prospects given by these sectors and their unquestionably bright future. The abundance of natural water resources and the diversity of the aquatic ecosystem are a benefit to the Nigerian economy, which has the potential to generate enormous earnings from the aquaculture and fishing industries. The goal of boosting production that satisfies domestic demand and, ideally, increases export opportunities might be aided by the abundance of human resources, particularly in rural areas. With a long-term sustainable plan, scientific and technological study on native fish species, proper hygiene management, and enhanced disease control, Nigeria's current aquaculture situation may be improved.

REFERENCES

Amosu, A. O., Hammed, A. M., Togunde, K. A., Joseph, O. O. and Adekoya, A. (2017). Possible aquaculture development in Nigeria: Evidence for commercial prospects. *Journal of Agricultural Science and Technology*, B (7), 194-205.

Box, G.E.P. and Jenkins, G.M. (1976). *Time Series Analysis: Forecasting and Control*, Revised Edition, San Francisco: Holden Day.

Christopher, L. D., Nikolas, W., Mark W., Rosegrant, S.M., and Mahfuzuddin A. (2020). The Future of Fish, Issues and Trends. Worldfish Centre.

FAO. (2020a). Fisheries and aquaculture statistics. Global aquaculture and fisheries production 1950–2018 (Fishstat). Rome: FAO Fisheries and Aquaculture Department.

FAO. (2020b). The State of World Fisheries and Aquaculture. Sustainability in Action, Food and Agricultural Organization of the United Nations, Rome, Italy,

Federal Ministry of Finance, Budget and National Planning (2020). National Development Plan 2021-2025.

Garcia, S. M. and Rosenberg, A. A., (2010) "Food security and marine capture fisheries: characteristics, trends, drivers and future perspectives," *Phil Trans R.Soc. B,* 365, 2869–2880.

National Bureau of Statistics [NBS], (2020). 2019 Poverty and inequality in Nigeria. Abuja, Nigeria: NBS.

Pauly, D., Alder, J., Bennett, E., Christensen, V., Tyedmers, P. and Watson, R. (2003) The future of fisheries. *Science*, 302, 1359-1361.

Subasinghe, R., Siriwardena, S. N., Byrd, K., Chan, C. Y., Dizyee, K., Shikuku, K., Tran, N., Adegoke, A., Adeleke, M., Anastasiou, K., Beveridge, M., Bogard, J., Chu, L., Fregene, B. T., Ene- Obong, H., Cheong,

K. C., Nukpezah, J., Olagunju, O., Powell, A., Steensma, J., Williams, G., Shelley, C. and Phillips, M. (2021). Nigeria fish futures. Aquaculture in Nigeria: Increasing Income, Diversifying Diets and Empowering Women. Report of the scoping study. Penang, Malaysia: *WorldFish*. Program Report: 2021-16.

World Data, (2022). Knoema, Nigeria Population, 1960-2022

WorldFish, (2021). WorldFish in Nigeria. https://www.worldfishcenter.org/where-we- work/africa/Nigeria

HAZARD ANALYSIS OF HEAVY METALS BUILDUP IN THE DREGS OF BAKAJEBA RESERVOIR, PAIKORO, NIGER STATE, NIGERIA

[1]HAMZAT A., [2]A.S. DAN-KISHIYA, [2]R.T. IDOWU, [3]M.K. YUSUF, [3]A. B. LIMAN, [*4]A. IBRAHIM AND [5]N.O. YUSUF

[1]*Department of Biological Sciences, Ibrahim Badamasi Babangida University bai, Lapai, Niger State, Nigeria.*

[2]*Department of Biological Sciences, University of Abuja, P.M.B. 117, Abuja Nigeria.*

[3]*Department of Animal Production, Ibrahim Badamasi Babangida University, Lapai.*

[4]*Department of Water Resources, Aquaculture and Fisheries Technology, Federal University of Technology P.M.B. 65 Minna, Niger State, Nigeria.*

[5]*National Biotechnology Development Agency, Abuja, Nigeria.*

***Corresponding Author:** a.ibrahim@futminna,edu..ng, +2348060494372

ABSTRACT

Bakajeba reservoir is a vital source of water for different needs in the region. Pollution from different sources may negatively affect the suitability and water quality of the reservoir. Accordingly, this study aimed to monitor changes in heavy metal buildup in dregs sampled monthly from the reservoir. Three sampling sites were selected for the study: S1, S2 and S3. The sediment samples were taken between November 2018 and October 2020 using the Ekman Grab. Samples collected were digested and analyzed for heavy metals, using an atomic absorption spectrophotometer for the summary and inductive statistics of the data. The results present lead, copper, zinc, iron, cadmium, and chromium concentrations with ranges as 0.33±0.13 - 0.38±0.02 mg kg^{-1}, *0.28±0.17 - 0.39±0.03* mg kg^{-1}, *0.17±0.02 - 0.24±0.04* mg kg^{-1}, *0.24±0.01 - 0.39±0.03* mg kg^{-1}, *0.42±0.07 - 0.49±0.0* mg kg^{-1}*7, and 0.41±0.04 - 0.46±0.03* mg kg^{-1}, *respectively. Except for Zinc and iron, the concentration levels of other heavy metals in all stations exceeded the limits recommended by the FAO for domestic and aquaculture use. This suggests a degradation of ecological integrity and highlights an urgent need for restoration efforts.*

KEYWORDS: Sediment, Acid digestion, Spectrophotometer, Ekman Grab, Azotic acid, Bakajeba Reservoir

INTRODUCTION

The health risks to human and aquatic organisms are the main concerns regarding heavy metal buildup in aquatic dregs (da Silva *et al.*, 2017). These contaminants are attributable to sources like sugarcane farming practices, municipal and atomic effluents (Nasehi *et al.*, 2013).

Environmental degradation in aquatic systems essentially include heavy metals pollution (Aldwila *et al.*, 2018). The dangers of heavy metals lie in their non-degradability and collection on surfaces of the earth. By implication, soil heavy metals may end up in the human body and livestock, with direct or indirect health risks (World Health Organization, 2015). Freshwater always contain trace amount of heavy metals from continental sources, including weathering of rocks leading to repeat of a heavy metals cycle in the aquatic ecosystems (Zeng *et al.*, 2020). Immobilized microelements in aquatic dregs could result in absorption, co-precipitation, and formation of complexes (Chen *et al.*, 2023). Sometimes, oxides and hydroxides of iron (Fe) and manganese (Mn) are co-adsorbed or may occur in the form of particulate matter (Al-Hashem *et al.*, 2022). The history and degree of pollution can be revealed using trace element concentrations in stream sediment compartments (Mohiuddin *et al.*, 2010). For their fluctuating physical and chemical properties, sediments play a vital role in the sequestration of contaminants in aquatic systems (Mandal *et al.*, 2021; Patel *et al.*, 2022). Pollutants assessment in sediments is necessary due to their absorbent capability by suspended material and fine-grained particles. Heavy metals are harmful elements that can pose significant health and environmental risks when their concentrations surpass certain levels. The local population uses the sediment from the reservoir for a variety of purposes, including irrigation, fishing, and household use. Despite this, there is a lack of sufficient monitoring or regulation of water quality and the potential dangers of heavy metal contamination. As a result, this study was conducted to evaluate the concentration of heavy metals in the Bakajeba reservoir's sediment to ascertain its pollution status and to underscore the connections between the stations. The study highlights health risks and environmental impacts, underscoring the need for water quality regulation. It also educates locals on contamination dangers and informs future research on prevention and remediation strategies.

MATERIALS AND METHODS

Study Area

Bakajeba Reservoir is an earthen embankment Dam located at Bakajeba village in Paikoro Local Government Area of Niger State. It was built by the Upper Niger River Basin Development Authority (UNRBDA) to supply water for irrigation and aquaculture for communities in Paikoro and Lapai Local Government areas of the state.

Bakajeba reservoir lies in Latitude 9°12' 0"N - 9°14' 40"N and Longitude 6°35' 20"E - 6°40' 00"E (fig. 1). The terrain is a rugged type with sparse -thick bushes and farms. It extends roughly 1.1km crest dimension with 16m overall height, and a 38 million m^3 storage volume. Bakajeba Reservoir takes its source from the popular Gurara Dam (URNDA, 2012). It is counted among the aged water bodies stretching 2 km^2. The surrounding communities include Bakajeba, Tungan Gana, Aduru, Shikakpi, Chimbi, Tatiko, Zole, Mari, Ungwan Umaru, Ungwan Usman and Lenfa. The project was initially intended for storage, irrigation and other beneficial uses during construction in 2007 and commissioning in 2012 (URNDA, 2012). Part of the project plan was a 10,000 m^3/day treatment plant, with 23km and 30km conveyance conduits to Lapai and Agaie, correspondingly. It supplies water to reservoirs at Agaie (2,000m), Lapai (1,000m) and villages along the conduit's route (30m) in the nearest future. (EIA, 2007; Hamzat *et al.*, 2021).

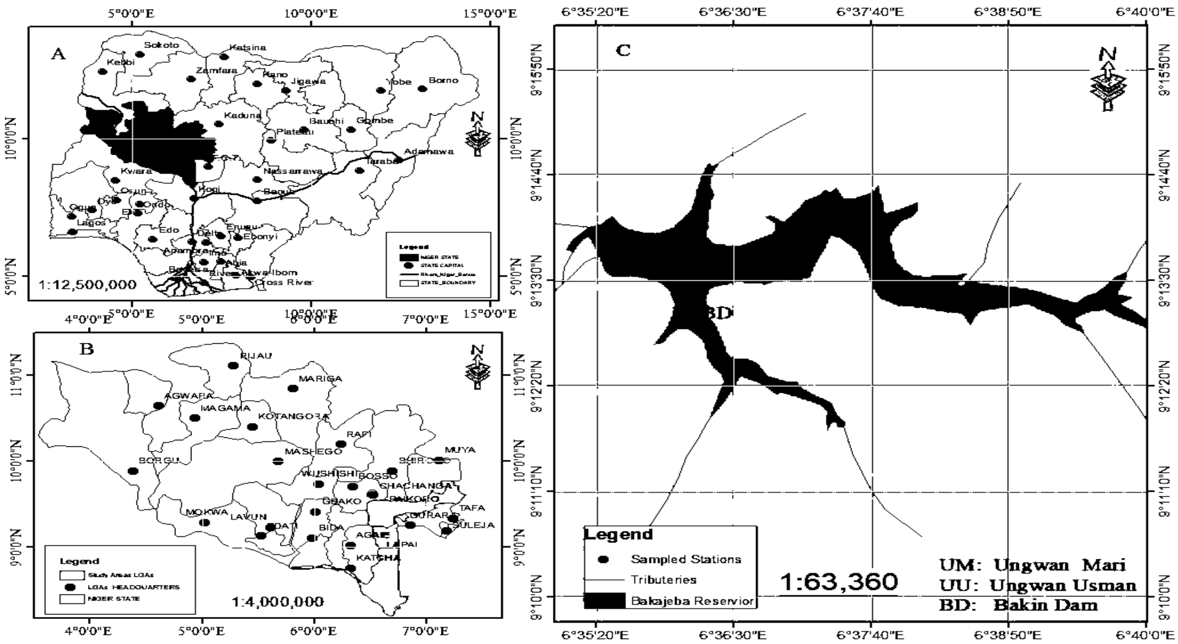

Fig. 1: A. Inset maps: A. Niger state inset Nigeria; B. Paikoro Local Government Area inset Niger state, C. Hydrological map of Bakajeba reservoir showing the sampling stations.

Source: Remote Sensing/ Geographical Information System Laboratory, Department of Geography, FUT MINNA (2018).

Sampling stations

Three sampling stations were chosen based on human and agricultural activities and adjoining tributaries, as shown in Table 1 below.

Table 1: A brief account of the research sampling stations.
Legend: S1 (UU): station 1 (Ungwan Usman); S2(UM): station 2 (Ungwan Mari); S3(UD): station3 (Bakin Dam)

Station	Coordinates	Description
S1 (UU)	Latitude 9°13ꞌ50.658"N; longitude 6°35'34.122″E	This is the reservoir's largest inlet/tributary. Fishing canoes are always anchored here. Putrefying plant materials and domestic discharges and agricultural wastes are common in this location. It lies at 210.70m elevation above sea level.
S2 (UM)	latitude 9°13ꞌ44.504"N; longitude 6° 36ꞌ41.816"E	This area has large human settlements dotted with mini markets. It is a major transportation route for dwellers of communities around the reservoir. It is at 214.00m above sea level.
S3 (BD)	latitude 9°13ꞌ6.701"N; longitude 6°36ꞌ9.288"E	It is the local farmers' and fishers' principal landing site—a commercial hub with great anthropogenic activities in associated fish market. Domestic wastes attributed to the marked are emptied into the reservoir here. Macroinvertebrates are often seen at the reservoir's bank here. It is located at 217.20m above sea level.

Collection of sediment samplesfor heavy metals analysis

Ekman Grab was used to collect sediments from the reservoir in all sampling stations for heavy metal analysis. Sediment collection was achieved by lowering the Ekman Grab via a rope into the reservoir until it touches the floor of the reservoir. The grab's weight is allowed to encore it into the sediment at the depth. A pull of the line closes the grab's two arms to collect the dregs. Collected dregs were discharged into labelled container and conveyed to the laboratory for further processing.

Digestion of sediment samples

Samples of the sediments were air dried for three days, broken into smaller particles, and sieved. A gram of each sieved dregs sample was weighed into a beaker. 10ml Nitric acid (HNO_3) and 10ml hydrochloric acid (HCl) were added and heated in a water bath for 75 minutes at 150˚C until the choking odour was clear. The samples were removed to cool off for 25 minutes at room temperature. The resultant samples were then sieved into a 100cm^3 graduated flask. The filtrate amplified to 25ml (Olafisoye *et al.*, 2013). The sample solutions were distributed into prepared and labelled sample tubes for heavy metals determination using the Atomic Absorption Spectrophotometer (AAS).

Heavy metal analysis

Specific metals: lead (Pb^+), copper (Cu^+), zinc (Zn^+), Fe^+, cadmium (Cd^+), and chromium (Cr^+) absorbances from digested materials were measured in clear supernatants using the *Unican 939 Atomic Absorption Spectrometry and MY I5150001.*

RESULTS

As shown in Table 2, the highest mean lead concentration 0.38±0.02 mg kg^{-1} in sediment was detected in S1, while the least 0.33±0.13 mg kg^{-1} was detected in S3. The peak average build of copper was in S3 at 0.39±0.03 mg kg^{-1}, while the lowermost 0.28±0.17 mg kg^{-1} was in S1. Zinc concentration of the stations showed 0.24±0.04 mg kg^{-1} in S3 and 0.17±0.0 (least) in S1. The value, 0.39±0.03 mg kg^{-1} (the greatest) concentration (in S3) of Iron$^+$ across stations, while the lowermost 0.24±0.01mg kg^{-1} was in S2. Cadmium peaked at 0.49±0.07 mg kg^{-1} (S3), while 0.42±0.07 mg kg^{-1} was the least value (S1). The Chromium value peaked at 0.46±0.03 mg kg^{-1} in S3 and was at the least concentration 0.41±0.04 mg kg^{-1} in S1 as shown in Table 2. These values are in excess of the recommended ranges for domestic and aquaculture uses, except for the concentrations of zinc and iron. The different concentration levels of lead showed the greatest 0.38 mg kg^{-1} concentration in S1 in December while S2 has the least, 0.33 mg kg^{-1} in November and December. There were variations in the concentration across the stations in other months, as shown in Fig. 2-7.

The monthly variation in zinc concentration shows the peak concentration of 0.46 mg kg^{-1} in November and December (S3). Hence, the variation shows a steep waning in February through October, with a minor increase in February (S3) as it decreases across the stations, with the least, 0.1 mg kg^{-1} (S2) in October (Fig. 4). The result of sediment concentration of iron in Bakajeba reservoir in Fig. 5, shows value fluctuations between 0.1 mg kg^{-1} and 0.55 mg kg^{-1} across February - April. Cadmium rose to its peak value: 0.80 mg kg^{-1} in August, while it was in its build up, 0.15 mg kg^{-1} in April. The year saw a steady and uneven decrease in the buildup, with the highest point in February and the lowest point in November - December. The decrease proceeded from January to June except in May. The pattern of the fluctuations indicates that 0.7 mg kg^{-1} was recorded in February, and then declined to 0.2 mg kg^{-1} in November and December. Slight fluctuations in the concentrations across the months were also observed as shown in fig. 7. Copper declined from 0.57 mg kg^{-1} in February to 0.2 mg kg^{-1} in January, (Fig. 3).

Table 2: Mean ± Standard Error of heavy metals variation in the sediment of Bakajeba Reservoir (November 2018 - October 2020)

Sampling points	**Mean ± SE values of heavy metals (mg kg^{-1}) concentration**					
	Pb^+(mg kg^{-1})	Cu^+(mg kg^{-1})	Zn^+ (mg kg^{-1})	Fe^+(mg kg^{-1})	Cd^+(mg kg^{-1})	Cr^+(mg kg^{-1})
Station-1	0.38±0.02^b	0.28±0.17^a	0.17±0.02^a	0.25±0.00^a	0.42±0.07^a	0.41±0.04^a
Station-2	0.35±0.16a^b	0.35±0.02^b	0.20±0.02^a	0.24±0.01^a	0.43±0.08^a	0.44±0.03^a
Station-3	0.33±0.13^a	0.39±0.03^b	0.24±0.04^a	0.39±0.03^b	0.49±0.07^a	0.46±0.03^a
FAO,2011	0.2	0.2	2	5	0.001	0.1
USEPA, 2018	0.015	1	5	0.3	0.005	0.1

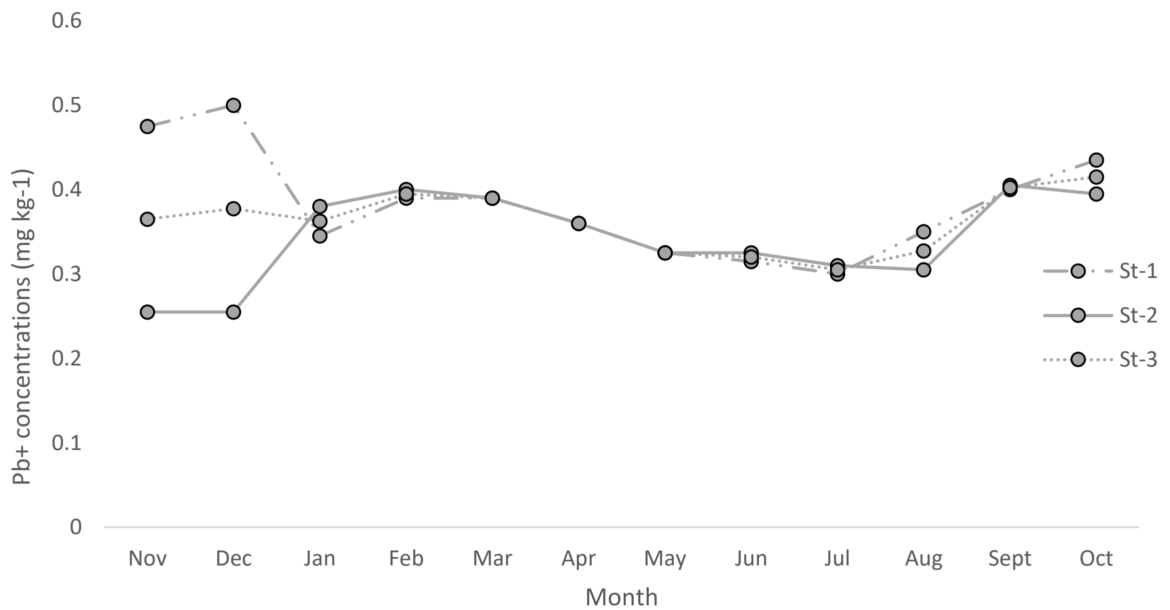

Fig. 2: Monthly variation of Lead in the dregs sample of Bakajeba reservoir from Nov. 2018 -Oct. 2020.

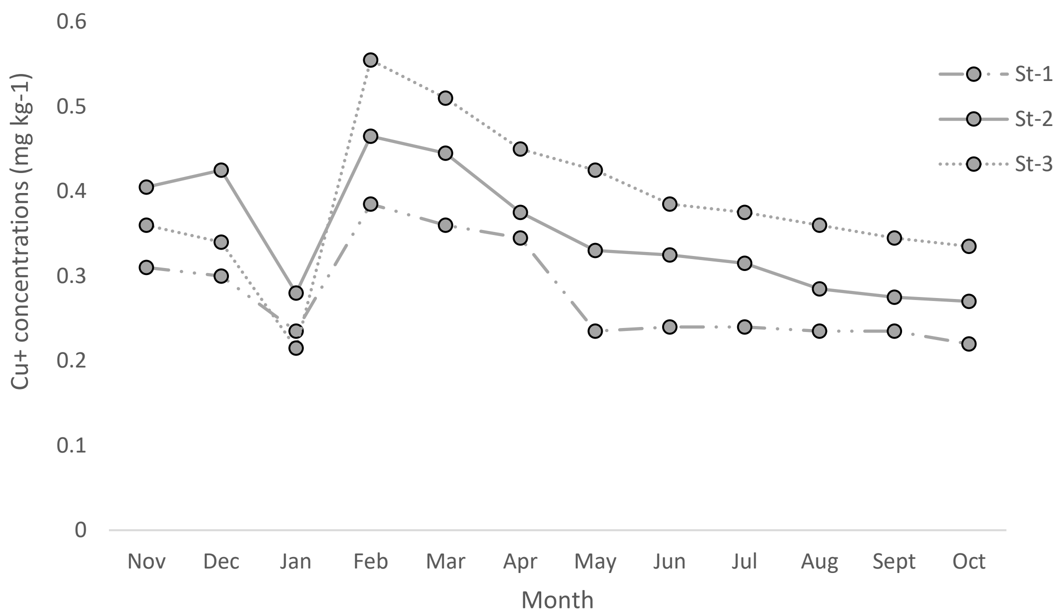

Fig. 3: Monthly variation of copper in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

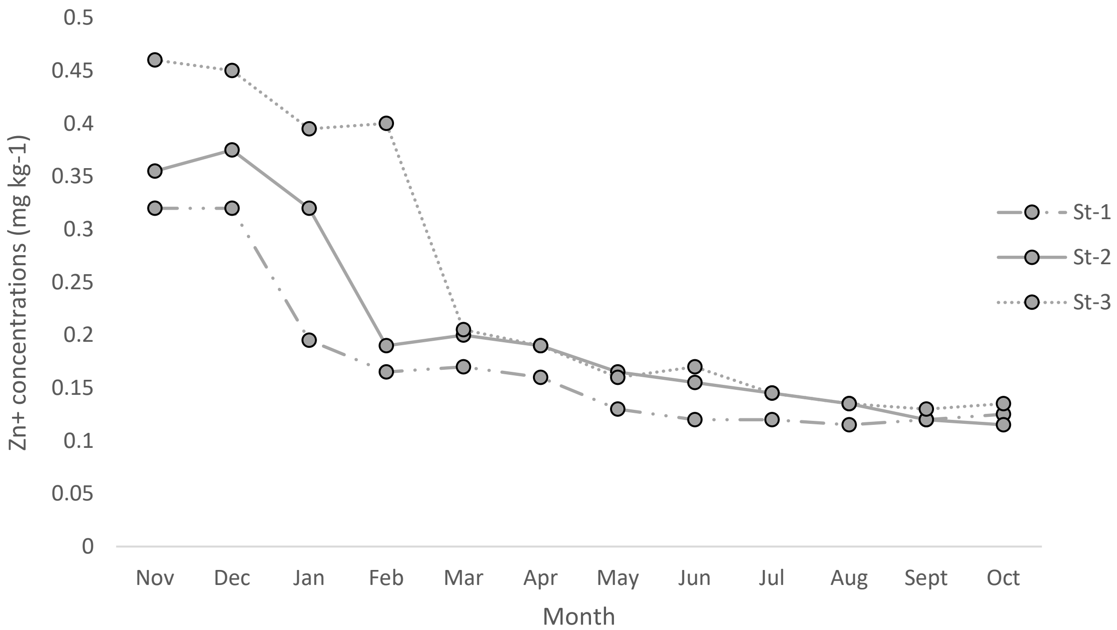

Fig. 4: Monthly variation of Zinc in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

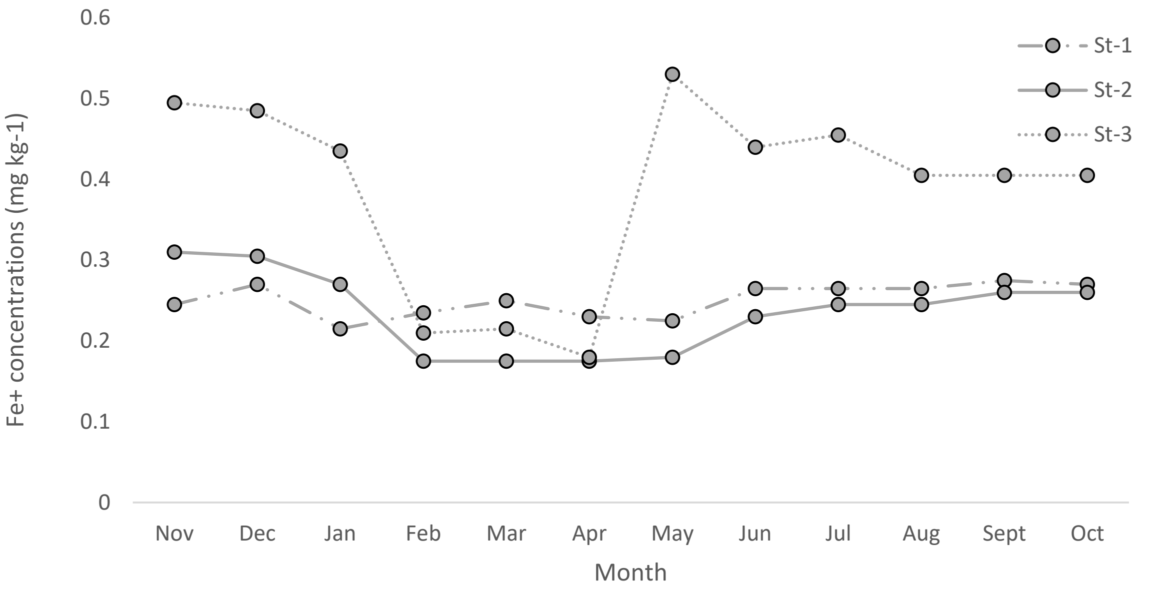

Fig.5: Monthly variation of Iron in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

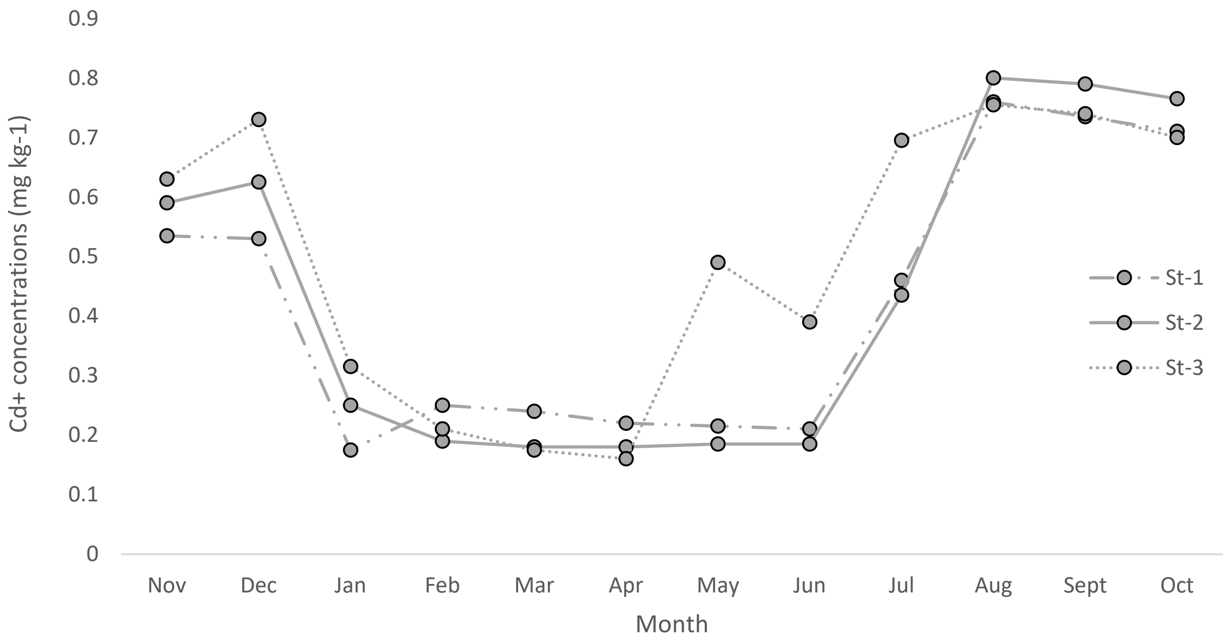

Fig. 6: Monthly variation of Cadmium in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

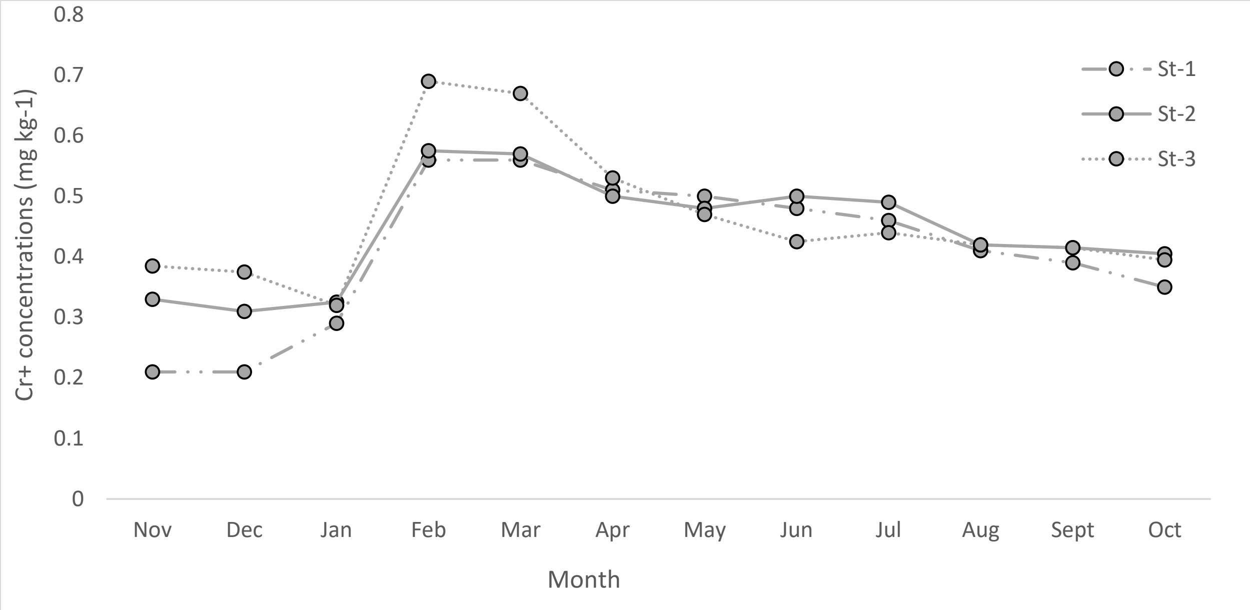

Fig.7: Monthly variation of Chromium in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

DISCUSSION

The importance of determining heavy metals concentration in water bodies cannot be over emphasized due to health implications associated with its high concentration. In this investigation, the average concentration of Zn^{+} and Fe^{+} falls within the recommendation set by (World Health Organization, 2011, 2015) while all other heavy metals detected were above the recommendation for drinkable water.

One of the dangers of lead is that it builds up in the skeletal system and over time it becomes virulent to the central and peripheral nervous systems, thereby, causing Subacute encephalopathy neurological and behavioral effects (World Health Organization, 2015). The concentration of Pb^{+} in the sediment observed in this reservoir was (0.38±0.02 mg kg^{-1}), which is above the recommended value for Pb^{+} in drinkable water (0.01). Mwegoha and Kihampa (2010) and Asare *et al.* (2018), , reported 0.04 mgL^{1} of Pb+ in Uke Stream Nasarawa State, and the Bontanga Reservoir, Ghana respectively, Opaluwa *et al*. (2012) and Ergönül *et al.* (2020), reported 0.08 of Pb^{+} from Dares Salaam City, Tanzania, Ali *et al*. (2011) and Kawichai (2023), observed 1.20 mg kg^{-1} of Pb+ in the red sea at Jeddah Islamic port coast and in Sediment Samples from the Mae Chaem River, Chiang Mai, Thailand respectively. These show that anthropogenic sources (effluent from farmland, and sewage from human settlements around dam) or environmental factors sometimes determine the levels of Pb^{+} concentration. Khosravi *et al.* (2011), observed 0.0036 mg kg^{-1} average concentration of Pb^{+} in sediment from Anzali wetland, which is less than the value observed in this investigation. The monthly variation between 0.25 - 0.53 mg kg^{-1} in November and December, with fluctuations between the stations, could be due to the discharge of effluents from the nearby communities. The high concentration of Pb^{+} might be due to waste discharge from industry, homes as well as agro-chemicals and fertilizers used in arable land close to the reservoir. All these wastes contained substances that are rich in Pb^{+} (Mico *et al.*, 2006; Mekuria *et al*., 2021). In addition to these sources, Geological activities near the reservoir contribute immensely to the high concentration of Pb^{+}.

All natural waters and sediments contain copper and zinc as micronutrients. Despite their minor nature, both can be toxic to aquatic life at concentrations above the minimum thresholds required (Bai *et al.*, 2011; Abirami *et al*., 2023). The sediment of the reservoir contains Cu^{+} at a level ranging from 0.28±0.17 to 0.39±0.03 mg kg^{-1}, based on the measurements obtained in this study the concentration of Cu^+ from all the sampling points exceeded the recommendation set by WHO (2.0). The average concentration of Cu+ in sediment from the Anzali wetland was reported as 4.45mg kg^{-1} (Khosravi *et al.*, 2011; Jia, 2021), which is above the level observed in this present investigation. A 3.0 of Cu^+ conc. in sediments of a stream in southwestern Turkey. Edward *et al.* (2013) and Maghsoudi Moud (2022) reported 0.84 concentration of Cu^+ from Odo-Ayo River in Ado-Ekiti-State, Nigeria and from the Kerman metallogenic belt, SE Iran respectively. This was a little bit above the value observed in this investigation. However, the differences between these present findings and those of other authors may be due to differences in the history of the sites excavating activities and the reservoir dilution factor. A large body of research has shown that Zn^+ poses a low risk to human health when it enters water bodies, but a high risk to aquatic organisms, especially fish. (Olafisoye *et al.*, 2013, Li *et al*. 2021). Although, of all the heavy metals, Zn^+ is less toxic but at high conc. it affects the quality of water in the reservoir such as giving a bitter and metallic taste to the water and, in an alkaline environment, the water becomes turbid (Dean *et al.*, 2006; Ochiba, 2020). The sediment of the reservoir had the highest average levels of Zn^+ among all the samples collected in the study. (0.15±0.03 and 0.24±0.04) with no significant difference ($p>0.05$) across the stations. Fluctuations of Zn^+ levels in the examined sediment of the reservoirs confirm that zinc abounds in the sediment because of its release from the surface water by low mobility of Zn^+ during organic matter mineralization and photo-chemical degradation (Dean *et al.*, 2006; Velempini *et al.*, 2021). This agrees with the study of Sobczynski and Siepak (2001), Cimboláková *et al*. (2020), on Zn^+ in the sediments of lakes in Wielkopolski National Park. The results of this current study fall within the 3.0 and 5.0 recommendation set by WHO for drinkable water (World Health Organization, 2011).

The mean concentrations of Fe^+ in sediment showed between 0.24±0.01 to 0.39±0.03 mg kg^{-1} (Stations 3 and 2). There were no differences in the concentration of Fe^+ at the upstream area of the reservoir but a higher concentration was obtained in the middle area of the reservoir. The differences in the concentration of Fe^+ in the downstream and upstream might be due to high human activities going on at the downstream that contaminate the reservoir. The results obtained in this investigation agrees with Edward *et al.* (2013), who both reported 0.27 and 0.83, and Dalcin Martins (2021), who both reported 0.27 concentrations of Fe^+ in water and sediment samples from Odo-Ayo River in Ado-Ekiti, Ekiti-State, Nigeria. Sabo *et al.* (2013), reported 0.3 of Fe^+ concentration in River Delimi, Jos, Nigeria, which is a little bit higher than recommendation set by WHO for drinkable water.

High concentration of cadmium (Cd^+) in drinkable water can result to debilitating health issues, such as several acute and chronic disorders which can result to "itai-itai" disease, renal damage, emphysema, hypertension, and testicular atrophy (Agarwal *et al.*, 2005; Kaur and Sharma, 2021). Another danger of Cd^+ is that it is non-degradable and persist in the environment for long time (Rahman and Singh, 2019).

The maximum and minimum average concentrations of Cd^+ in sediment observed in this present study were 0.42±0.07 to 0.49±0.07 mg kg^{-1}, which shows high concentration in all samples, and it is also above the recommended limits set by WHO. According to WHO, the concentration of Cd^+ in drinkable water should not be more than 0.003 (World Health Organization, 2011). The high concentration of Cd^+ obtained in this investigation could be due to activities of the fish vendors visiting the area and cars, tricycle, motorcycle and bicycle were being washed into the reservoir from the upstream and this flows downstream, thereby, contaminating the downstream part of the reservoir with Cd^+. Yang *et al.* (2005), Tang et al. (2019), reported a high concentration of Cd^+ in sediments of Baiyanddian lake which resulted from severe pollution and, 0.57 concentration of Cd^+ in sediment from various locations. As stated by World Health Organization (2011), that, Cd^+ finds its way into the water bodies in wastewater and pollution caused from fertilizer usage. Surface water may be contaminated because of different forms of fertilizer used by the farmers and the runoff from this farm area is the primary cause of increase level of Cd^+ concerning the area of this study, however, because of increase in farm activities such as, the use of agrochemicals and fertilizers close to the study area, has resulted into high concentration of heavy metals in the reservoir and its sediments, more so, excavation activities is an important indicator in the high concentration of heavy metals in water bodies. Another heavy metal detected in this present investigation was chromium (Cr^{+}), according to World Health Organization (2011), Cr^{+} could cause cancer and as well as changing the genetic make-up of an organism and excessive exposure to it, can lead to cancer of the lungs, irritation of the skin, kidney and liver destruction. Based on this health implications, World Health Organization (2011), gave a recommendation on the limit of concentration of chromium in drinkable water not to be more than 0.05. Siddiqui and Pandey (2022) observed that Cr^{+} finds its way into water bodies via aerial deposition or surface run off. In this current investigation, the maximum and minimum concentration of Cr^{+} were 0.46±0.03 and 0.41±0.04 mg kg^{-1} from station 3 and station 1 respectively and the values were above the recommendations of the World Health Organization (2011). An inland fresh water was investigated by Olatunji and Osibanjo (2012) and Usman *et al*. (2022), who reported 2.08 concentration of Cr^{+} in River Niger and River Osara North central Nigeria and from Cika Koshi reservoir Katsina North-western Nigeria respectively, above the concentrations reported in this study.

Waseem *et al.* (2014), reported a range of 0.16 to 0.29 of Cr^{+} concentration in Bara River, Nowshera, KPK province, Pakistan for surface water contamination, which almost in the same range with what is observed in this study. Similarly, (Gao *et al.*, 2013), obtained 0.22 Cr^{+} concentration in wetland soils of typical shallow freshwater lakes in China.

Conclusion

This study revealed that the levels of heavy metals in the Bakajeba reservoir exceeded the standards for drinking water and aquatic life. This poses a serious threat to public health and biodiversity. The reservoir is under pressure from various human activities that contribute to the pollution. Therefore, urgent action is needed to protect the reservoir from further degradation and restore its quality.

REFERENCE

Abirami, S., Kadirvelu, K., and Baskar, S. (2023). Trace Metal Based Eco-Biological and Health Risk Status of Surface Water and Sediments of Noyyal River Basin, Tamil Nadu, India. Soil and Sediment Contamination: An International Journal, 1-30.

Agarwal, A., Singh, R. D., Mishra, S. K., and Bhunya, P. K. (2005). ANN-based sediment yield river basin models for Vamsadhara (India). *water SA*, 9-100.

Al-Hashem, A. A., Beck, A. J., Krisch, S., Menzel Barraqueta, J. L., Steffens, T., and Achterberg, E. P. (2022). Particulate trace metal sources, cycling, and distributions on the southwest African shelf. *Global Biogeochemical Cycles*, *36*(11), e2022GB007453.

Aldwila, N. M., Al Wosabi, M., Nagi, H., and Al Shwafi, N. (2018). Assessment of heavy metal pollution in the surface sediments of hadhramout coast, Yemen. *Advan. Clinic. Toxico* (31), 15.

Ali, A. A., Elazein, E. M., and Alian, M. A. (2011). Determination of Heavy Metals in Four Common Fish, Water and Sediment Collected from the Red Sea at Jeddah Islamic Port Coast. *Journal of Applied Environmental and Biological Sciences,* 1(10), 453-459.

Asare, M. L., Cobbina, S. J., Akpabey, F. J., Duwiejuah, A. B., and Abuntori, Z. N. (2018). Heavy metal concentration in water, sediment and fish species in the Bontanga Reservoir, Ghana. *Toxicology and Environmental Health Sciences*, 10, 49-58.

Bai, J., Cui, B., Chen, B., Zhang, K., Deng, W., Gao, H., and Xiao, R. (2011). Spatial distribution and ecological risk assessment of heavy metals in surface sediments from a typical plateau lake wetland, China. *Ecological modelling*, *222* (2), 301-306.

Chen, W., Tang, H., Li, H., Zhao, Y., Wang, X., Chen, J., Chen, Z., Zhu, Y., and Yang, W. (2023). Efficient defluoridation of water by utilizing nanosized Ce-Fe bimetal oxyhydroxides encapsulated inside porous polystyrene anion exchanger. *Chemical Engineering Journal*, *461*, 141820.

Cimboláková, I., Uher, I., Laktičová, K. V., Vargová, M., Kimáková, T., and Papajová, I. (2020). Heavy metals and the environment. *Environ. Factors Affect. Hum. Heal*, 10.

Dalcin Martins, P., de Jong, A., Lenstra, W. K., van Helmond, N. A., Slomp, C. P., Jetten, M. S., ... and Rasigraf, O. (2021). Enrichment of novel Verrucomicrobia, Bacteroidetes, and Krumholzibacteria in an oxygen-limited methane-and iron-fed bioreactor inoculated with Bothnian Sea sediments. *MicrobiologyOpen*, 10(1), e1175.

da Silva, Y. J. A. B., Cantalice, J. R. B., Nascimento, C. W. A., Singh, V. P., Silva, C. M. C. A. C., and Guerra, S. M. S. (2017). Bedload as an indicator of heavy metal contamination in a Brazilian anthropized watershed. *Catena*, *153*, 106-113.

Dean, R. J., Shimmield, T. M., and Black, K. D. (2006). Copper, Zinc and Cadmium in marine cage fish farm sediment: An extensive survey. *Environmental Pollution*, *145*, 84-95.

Edward, J. B., Idowu, E. O., Oso, J. A., and Ibidapo, O. R. (2013). Determination of heavy metal concentration in fish samples, sediment and water from odo-ayo River in Ado-Ekiti, Ekiti-State, Nigeria. *International Journal of Environmental Monitoring Analysis*, *1*(1), 27-33.

EIA. (2007). *Environmental Impact Assessment Report of the proposed Bakajeba Reservoir Project. 2-3*

Ergönül, M. B., Nassouhi, D., and Atasağun, S. (2020). Modeling of the bioaccumulative efficiency of Pistia stratiotes exposed to Pb, Cd, and Pb+ Cd mixtures in nutrient-poor media. *International Journal of Phytoremediation*, *22*(2), 201-209.

Gao, H., Bai, J., Xiao, R., Liu, P., and Jiang, W. (2013). Levels, sources and assessment of trace elements in wetland soils of a typical shallow freshwater lake, China. *Stochastic Environment*, *27*, 275-284.

Hamzat, A., Dan-Kishiya, A., and Idowu, R. (2021). Determination of heavy metals associated with surface water of Bakajeba reservoir, Niger state, Nigeria. *International Journal of Fisheries and Aquatic Studies*, *9*(6), 313-319.

Jia, C., Chen, Q., Hao, D., Lou, S., An, M., Li, Q., ... and Cheng, W. (2021). Ground water copper levels in the seawater intrusion area and the possible physical and chemical dynamics. *Environmental Science: Processes and Impacts*, 23(2), 335-343.

Khosravi, M., Bahramifar, N., and Ghasempouri, M. (2011). Survey of heavy metals (Cd, Pb, Hg, Zn and Cu) contamination in sediment of three sites in Anzali wetland. *Iran Journal of Environmental Health*, *4*(2), 223–232.

Kaur, M., and Sharma, A. (2021). A review on heavy metal accumulation and toxicity in biotic and abiotic components. In *IOP Conference Series: Earth and Environmental Science* (Vol. 889, No. 1, p. 012062). IOP Publishing.

Kawichai, S., Prapamontol, T., Santijitpakdee, T., and Bootdee, S. (2023). Risk Assessment of Heavy Metals in Sediment Samples from the Mae Chaem River, Chiang Mai, Thailand. *Toxics*, 11(9), 780.

Li, L., He, Y., Song, K., Xie, F., Li, H., and Sun, F. (2021). Derivation of water quality criteria of zinc to protect aquatic life in Taihu Lake and the associated risk assessment. *Journal of Environmental Management*, 296, 113-175.

Maghsoudi Moud, F., Abbaszadeh Shahri, A., van Ruitenbeek, F., Hewson, R., and van der Meijde, M. (2022). Evaluation of the modified AHP-VIKOR for mapping and ranking copper mineralized areas, a case study from the Kerman metallogenic belt, SE Iran. *Arabian Journal of Geosciences*, 15(24), 1756.

Mandal, A., Dutta, A., Das, R., and Mukherjee, J. (2021). Role of intertidal microbial communities in carbon dioxide sequestration and pollutant removal: A review. *Marine Pollution Bulletin*, *170*, 112626.

Mekuria, D. M., Kassegne, A. B., and Asfaw, S. L. (2021). Assessing pollution profiles along Little Akaki River receiving municipal and industrial wastewaters, Central Ethiopia: Implications for environmental and public health safety. Heliyon, 7(7).

Mico, C., Recatala, L., Peris, M., and Sancchez, J. (2006). We are assessing pean Mediterranean area by multivariate analysis. *Chemosphere*, *65*, 863-872.

Mohiuddin, K. M., Zakir, H. M., Otomo, K., Sharmin, S., and Shikazono, N. (2010). Geochemical distribution of trace metal pollutants in water and sediments downstream of an urban river. *International Journal of Environmental Sciences and Techology*, *7*(1), 17-28.

Nasehi, F., Hassani, A. H., Monavvari, M., Karbassi, A. R., and Khorasani, N. (2013). Evaluating the metallic pollution of riverine water and sediments: a case study of Aras River. *Environmental Monitoring and Assessment*, *185*(1), 197-203.

Mwegoha, W. J. S., and Kihampa, C. (2010). Heavy metal contamination in agricultural soils and water in Dares Salaam City, Tanzania. *African Journal of Environmental Science Technology*, 4(11), 763-769.

Ochiba, N. K. (2020). Assessment Of Levels Of Selected Heavy Metals In Borehole Water In Ongata Rongai, Kajiado County, Kenya (Doctoral dissertation, University Of Nairobi).

Olafisoye, E. R., Sunmonu, A., Adagunodo, T. A., and Alagbe, O. A. (2013). Geophysical and hydro-physicochemical evaluation of hand-dug wells near a dumpsite in Oyo state, Nigeria. *Archives of Applied Science Research*, *5*(6), 29-40. www.scholarsresearchlibrary.com

Olatunji, O. S., and Osibanjo, O. (2012). Comparative assessment of some heavy metals in some inland freshwater fish species from river Niger and River Osara in North-Central Nigeria. *International Journal of Environmental Sciences and Techology*, *2*(3), 1842-1852.

Opaluwa, O. D., Aremu, M. O., Ogbo, L. O., Magaji, J. I., Odiba, I. E., and Ekpo, E. K. (2012). Assessment of heavy metals in water, fish and sediments from UKE stream, Nasarawa State, Nigeria. *Current World Environment*, 7(2), 213-220.

Patel, A. K., Singhania, R. R., Albarico, F. P. J. B., Pandey, A., Chen, C.-W., and Dong, C.-D. (2022). Organic wastes bioremediation and its changing prospects. *Science of the Total Environment*, *824*, 153889.

Rahman, Z., and Singh, V. P. (2019). The relative impact of toxic heavy metals (THMs)(arsenic (As), cadmium (Cd), chromium (Cr)(VI), mercury (Hg), and lead (Pb)) on the total environment: an overview. *Environmental monitoring and assessment*, 191, 1-21.

Sabo, A., Gani, A. M., and Ibrahim, A. Q. (2013). Pollution status of heavy metals in water and bottom sediment of river delimi in Jos, Nigeria. *American Journal of Environmental Protection*, *1*(3), 47-55.

Siddiqui, E., and Pandey, J. (2022). Atmospheric deposition: an important determinant of nutrients and heavy metal levels in urban surface runoff reaching to the Ganga River. *Archives of Environmental Contamination and Toxicology*, 1-15.

Sobczynski, T., and Siepak, J. (2001). Studies on accumulation of biogenic compound and speciation of metals in bottom sediments of lakes in Wieldkopolski National park. *Zesz. Nauk. Wydz. Bud.*, *20*, 265-290.

Tang, B., Tong, P., Xue, K. S., Williams, P. L., Wang, J. S., and Tang, L. (2019). High-throughput assessment of toxic effects of metal mixtures of cadmium (Cd), lead (Pb), and manganese (Mn) in nematode Caenorhabditis elegans. *Chemosphere*, 234, 232-241.

URNDA. (2012). *Upper Niger River Basin Development Authority, project report, 2012*.

Velempini, T., Prabakaran, E., and Pillay, K. (2021). Recent developments in the use of metal oxides for photocatalytic degradation of pharmaceutical pollutants in water—A review. *Materials Today Chemistry*, 19, 100380.

Usman, U. L., Muhammad, A. Z., Banerjee, S., and Musa, N. (2022). Bioaccumulation potential of heavy metals in some commercially fish species from Cika Koshi reservoir Katsina North-western Nigeria: Threat to ecosystem and public health. *Materials Today: Proceedings*, 49, 3423-3429.

Waseem, A., Arshad, J., Iqbal, F., Sajjad, A., Mehmood, Z., and Murtaza, G. (2014). Pollution status of Pakistan: a retrospective review on heavy metal contamination of water, soil, and vegetables. *BioMed research international*, *2014*.

World Health Organization, W. (2011). *Standard for Drinking Water Quality*. Geneva.

World Health Organization, W. (2015). *A field guide to African freshwater snails. West African Species, World Health Organization (WHO) Snail Identification Centre*. Pennak, E,1978

Yang, Z., Li, G., Wang, H., and Cui, T. (2005). Pollution and the potential ecological risk assessment of heavy metals in sediment of Baiyangddian Lake. *Journal of Agro-Environmental Science*, *24*, 945-951.

Zeng, J., Han, G., and Yang, K. (2020). Assessment and sources of heavy metals in suspended particulate matter in a tropical catchment, northeast Thailand. *Journal of Cleaner Production*, *265*, 121898.

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SEASONAL VARIATION OF IRON AND ZINC CONCENTRATION IN TISSUES OF SOME SELECTED FISH SPECIES FROM SHIRORO LAKE, NIGERIA

***[1] YUSUFU, F.O., [2] R.J. KOLO, [1]R.O OJUTIKU, [1]S.U IBRAHIM**
[1]Federal University of Technology Minna, Niger State.
[2]Crawford University, Igbesa, Ogun State
*Corresponding Author's E-mail: fridale2003@yahoo.com GSM: +2348052797077

ABSTRACT
Seasonal variation of iron and zinc concentration in tissues of some selected fish species (Clarias gariepinus, Copton zilli, Lates niloticus and Bagrus bajad) and their bioaccumulation in the gills, liver and muscle tissues of the four fish species from Shiroro Lake, were studied. Samples were stored and transported in ice chest to the Laboratory for determination of iron and zinc. The target organs (gills, liver and muscle tissue) of each sample were dissected and digested, heavy metal concentration in them were determined using atomic absorption spectrophotometer (AAS). The results indicated that, there was a significant difference seasonally in the mean value of iron and zinc accumulated. Rainy season had the highest while dry season had the least. Clarias gariepinus liver contained the highest concentration of zinc and iron. While Copton zilli had the lowest. The concentration of heavy metals in the target organs can be represented as; liver > gills > muscles for iron and zinc. Heavy metals found in the target organs were within and some below the WHO (2011) recommended permissible limits for consumption apart from iron found in the liver and gills of the fish species studied. Anthropogenic activities within the vicinity of Shiroro lake should be monitored and regulated.

Keywords: Bioaccumulation, gills, livers and muscles

INTRODUCTION

Globally, all living organisms largely depend on water for their livelihood while some live in it, some drink from it. Also, plants and animals require water that is moderately pure, and they cannot survive if their water is highly polluted Yusufu (2023). Concern about heavy metals contamination of fish has been motivated largely by the adverse effects on humans, given that consumption of fish is the primary route of heavy metal exposure. Heavy metals are defined as metallic elements that have a relative density compared to water (APHA, 2015). Heavy metals are also considered as trace elements because of their presence in trace concentrations in various environmental matrices. The origin of metals in the natural environment is either geogenic or anthropogenic releases (Nguyen *et al*., 2005). In Nigeria, due to increase population pressure and rapid urbanization, there has been increase in municipal water (sewage and industrial) effluent which eventually discharge in streams, lakes or rivers that flows through these cities and farmlands which constitute environmental pollution (Yusufu, 2023). Pollution arising from anthropogenic substance can alter a lake ecosystem and reduces its economic productivity. Heavy metals enter fish through gills, skin, oral in food and water. In the fish body the metals are transported through the blood stream and either stored, transformed or eliminated in the liver, kidney or the gills (Kigbu and Annune, 2019).

Concentration of heavy metal in aquatic organism varied between species, ages, sex and organs. Many field and laboratory studies showed that heavy metals accumulation in fish tissues depends on series of abiotic and biotic factors and their complexity, for example: fish species, its trophic levels, feeding habits, age and size, interspecific differences in sensitivity to various metals, concentrations of pollutants in water and sediment, the type of food, physical and chemical properties of water, the chemical element speciation and metal bioavailability (Canli and Atli, 2003).

Bio-accumulation refers to an increase in the concentration of a metal in a biological organism over time, compared to the normal concentration in the environment. Aquatic organisms bio-accumulate these trace metals in minute amount over time which later increases over a period. Fishes have been observed to be a good accumulator of the organic and inorganic pollutants in water (King and Jonathan, 2003).

The increasing importance of fish as a source of protein and the interest in understanding the accumulation of heavy metals at the tropic levels of food chain, extend the focus towards fish. Fish represents an important dietary and source of animal protein to Nigerians (FAO, 2017).

Therefore, the main purpose of this study was to assess seasonal variation of iron and zinc in the gills, liver and muscle tissues of *Clarias gariepinus*, *Copton zilli*, *Lates niloticus* and *Bagrus* *bajad* in Shiroro lake, Nigeria.

MATERIALS AND METHODS

Shiroro Lake is a man-made hydro-electric power generation dam constructed on River Kaduna in Shiroro Gorge in Niger State. It is located on latitude 9°57´N Longitude 6°13´E. It has an installed power generating capacity of 600 MW (Suleiman and Ifabiyi, 2015).

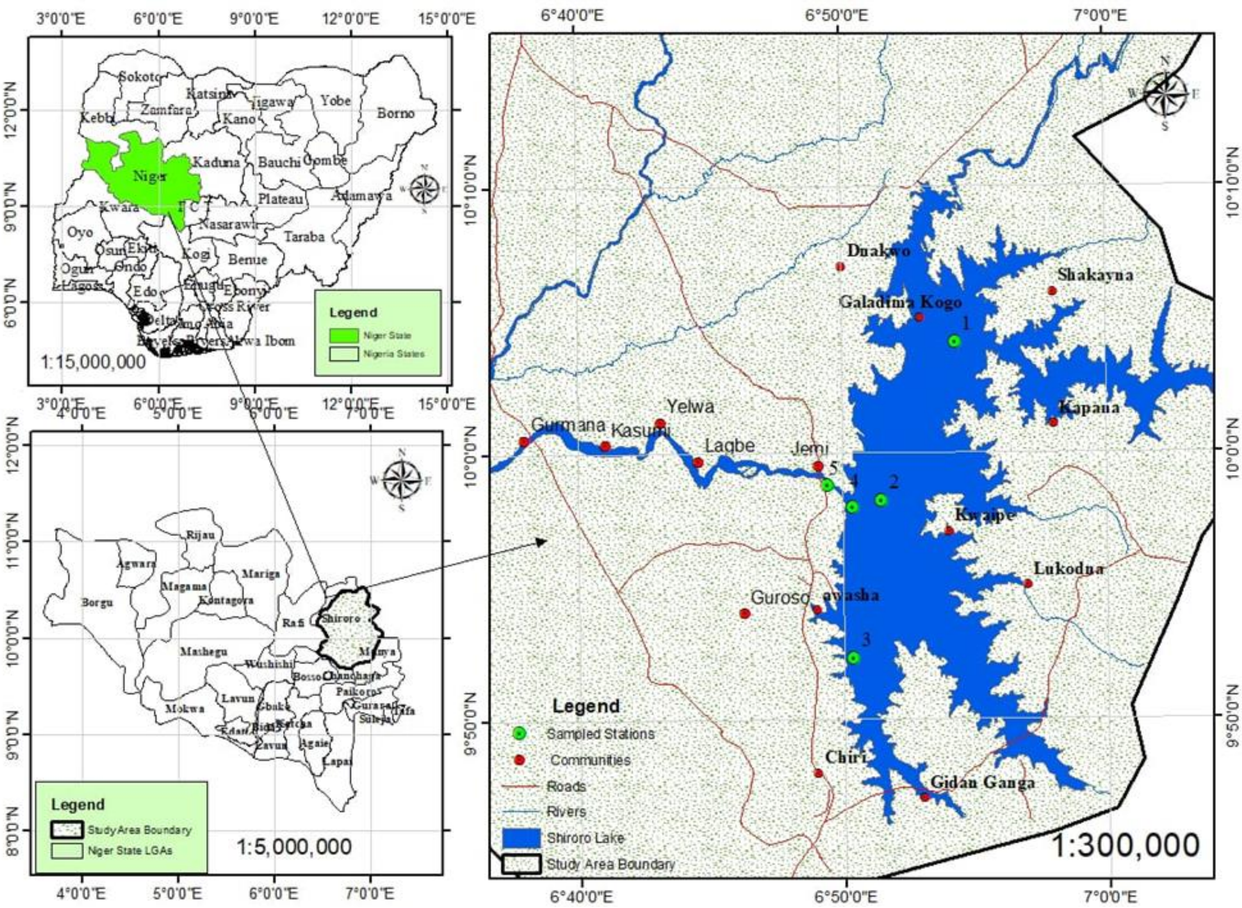

Figure 1: Location of the study area (Shiroro Lake)

Collection of Fish Samples

Fish samples selected were bought from the Fishermen at the landing sites, samples were stored and transported in ice chest to the Laboratory of Water Resources, Aquaculture and Fisheries Technology, Federal University of Technology, Minna, Nigeria for proper identification and examination. Fish identification was made to the lowest taxonomic level using identification guide book prepared by Olaosebikan and Raji (1998). Fish samples were collected monthly from October 2018-September 2020. The seasons were classified as May-July, Early rainy season (ERS), August – October, late rainy season (LRS), November – January, early dry season (EDS) and February – April, late dry season (LDS) .

Digestion of Fish Samples

Wet method of digestion was used as described by (APHA, 2015). Both the gills, tissue and liver were weighed (1g each) from various fish species, 20 ml of nitric acid was added and digested on hot plate at 150 °C till samples fully dissolved. Then 100 ml of distilled water was later added to the digested samples. It was then poured in a labelled sample bottle for further analysis.

Atomic absorption spectrophotometer was used to determine the level of various heavy metals in the different samples.

Determination of Metals using Atomic Absorption Spectrophotometer (AAS) (APHA, 1995)

Iron (Fe)

Stock Iron solution was prepared by dissolving 5.0503 g Iron (II) ammonium sulphate, Fe $(NH_4)_2(SO4)_2$ in 1 litre distilled water. Standard iron solution was prepared from stock solution in 1 litre of water from where different concentrations were prepared and determined for iron with AAS using iron cathode lamp at 248.3 nm. The samples were also run through AAS to determine for iron, the concentration of iron ions was extrapolated from the standard graph of the calibrated curve of the metal and presented in g/100g.

Iron was calculated using the equation:
Fe (mg/l) = reading from the curve X D

Where D = $ml\ sample + ml\ water + 1ml\ acid$ / ml of water (APHA, 1995)

Zinc (Zn)

Stock Zinc solution was prepared by dissolving clean 100 mg Zinc metal in 1 ml Hcl and to be made up to 1 litre with distilled water. Standard Zinc solution was prepared by making 10 ml of Zinc stock solution to 1 litre with distilled water. Different concentrations were also prepared from standard solution in the range of 0.1-0.5mg/l which was determined for Zinc with AAS using cathode lamp at 213.8 nm. The concentration of Zinc ions were extrapolated from the standard graph of the calibrated curve of the metal and presented in g /100g .It was calculated using the equation:

Zn (mg/l) = reading from the curve x D

Where D = $ml\ sample + ml\ water + 1ml\ acid$ / ml of water (APHA, 1995)

Data Analysis

One-way statistical analysis of variance (ANOVA) was used to determine the significant difference ($P<0.05$) in the mean concentration of iron and zinc in the fish tissue using Statistical Package for Social Science (SPSS) version 20.0 software. The differences among the means were separated using Duncan Multiple Range Test.

RESULTS

Table 1 shows the sub seasonal variation in iron and zinc concentration in the gills of the fish. The highest mean value of 9.67 mg/100g iron was recorded for late raining season (LRS) while the least mean value of 6.75 mg/100g was recorded for late dry season (LDS). Similarly, higher concentration of 1.14 mg/100g of zinc was also recorded for late raining season (LRS) while early dry season had the lowest concentration of 0.65 mg/100g. There was no significant difference ($p>0.05$) in the mean concentration of iron for early raining season and late dry season. A significant difference ($p<0.05$) was recorded in the mean concentration of others (late raining season and early dry season) sub season. In contrast, a significant difference ($p<0.05$) was recorded in the concentration of zinc among all the sub seasons

The sub seasonal variation in iron and zinc concentration in the liver of the fish. The highest mean value of 24.96 mg/100g of iron was recorded for late raining season (LRS) while the least of 11.66 mg/100g was recorded for late dry season (LDS). Similarly, higher concentration of 5.35 mg/100g of zinc was also recorded for late raining season (LRS) while the least of 1.74 mg/100g was recorded for early dry season. There was no significant difference ($p>0.05$) in the mean concentration of iron for early raining season and early dry season. There was significant difference ($p<0.05$) in the mean concentration of zinc among all the sub season.

The sub seasonal variation in iron and zinc concentration in the muscles of the fish. The highest mean value of 4.72 mg/100g of iron was recorded for early dry season (EDS) while the least, 3.49 mg/100g was recorded for early raining season (ERS). In contrast, higher mean concentration of 1.29 mg/100g of zinc was also recorded for late raining season (LRS) while the the least, 0.38 mg/100g was recorded for early dry season. There was a significant difference ($p<0.05$) in the mean concentration of early raining season and those of late dry season, early dry season and late dry season. The sub-seasonal mean variation of heavy metals concentration in the muscles of the experimental fish species. Except for iron that early dry season, EDS mean levels of iron found in the muscle was higher, other heavy metals had late rainy season, LRS with the highest mean value. There was significant difference ($P<0.05$) observed, and levels of heavy metals studied fell within the acceptable limits.

Table 1: Sub seasonal variation of iron and zinc Concentration in the gills, livers, and muscles of fish species

Organs	**Gills**		**Livers**		**Muscles**	
Season	**Fe(mg/100g)**	**Zn(mg/100g)**	**Fe(mg/100g)**	**Zn(mg/100g)**	**Fe(mg/100g)**	**Zn(mg/100g)**
ERS	6.77^{a}	0.87^{b}	16.85^{b}	3.62^{c}	3.49^{a}	0.96^{ab}
LRS	9.67^{c}	1.14^{c}	24.96^{c}	5.35^{d}	4.54^{b}	1.29^{b}
EDS	8.07^{b}	0.65^{a}	16.12^{b}	1.74^{a}	4.72^{b}	0.38^{a}
LDS	6.75^{a}	0.79^{ab}	11.66^{a}	2.77^{b}	4.01^{ab}	0.83^{b}
Permissible Limits WHO,2011	4.3	1	4.3	1	4.3	1
±S.E	0.22	0.04	0.76	0.19	0.14	0.07

Mean in the same Column carrying same superscript are not significantly different (P>0.05) Fe= Iron, Zn=Zinc, ERS= Early Rainy Season, LRS= Late Rainy Season, EDS= Early Dry Season, LDS= Late Dry Season

Table 2 shows that *Lates niloticus* liver accumulated less iron (13.65 mg/l) compared to other species examined. Also, *Lates niloticus* muscle tissue accumulated the least mean iron concentration of 3.54 mg/l. There was significant difference (P<0.05) between the mean concentration of iron in the gills, liver and muscle .*Copton zilli* gill had the least mean iron concentration, 6.35 mg/100g.There was significant difference (P<0.05) in the levels of iron concentration between the gills of the experimental fish species and above the permissible standard limits. Result also indicated that *Clarias* gill accumulated the highest level of zinc concentration, 1.20 mg/100g, while *Bagrus* gills recorded the lowest when compared to gills of other species. There was significant difference (P<0.05) in the level of iron deposited in the gills of the different fish species.

The mean concentration of heavy metals in the liver of the experimental fish species as shown in table 2. Among the heavy metals examined, iron, had the highest mean concentration level in the liver of all the fish species studied, which is above the (WHO, 2011) recommended limits.

The mean concentration of heavy metals found in the muscles of experimental fish species follows the trend of decreasing order; Fe>Zn. Iron among the heavy metals had the highest mean concentration level in the muscle of *Clarias*, 5.21 mg/100g while *Lates* had the least mean iron concentration found in the muscle, 3.54 mg/100g.There was significant difference (P<0.05).

Table 2: Mean Concentration of heavy metals in the gills, livers, and muscles of fish species

Organs	**Gills**		**Livers**		**Muscles**	
Fish Species	**Fe(mg/100g)**	**Zn(mg/100g)**	**Fe(mg/100g)**	**Zn(mg/100g)**	**Fe(mg/100g)**	**Zn(mg/100g)**
Clarias gariepinus	10.04^{c}	1.20^{b}	23.17^{b}	4.14^{b}	5.21^{b}	1.42^{b}
Coptodon zillii	6.35^{a}	0.80^{a}	16.22^{a}	2.76^{a}	3.89^{a}	0.55^{a}
Bagrus bajad	7.72^{b}	0.68^{a}	16.55^{a}	3.83^{b}	4.11^{a}	0.91^{a}
Lates niloticus	7.15^{ab}	0.77^{a}	13.65^{a}	2.75^{a}	3.54^{a}	0.58^{a}
Permissible limit (FAO/WHO,2011)	4.3	1	4.3	1	4.3	1
±S. E.	0.22	0.04	0.76	0.19	0.14	0.07

Mean in the same column carrying same superscript are not significantly different (P>0.05) Fe = Iron, Zn = Zinc

DISCUSSION

The study revealed that tissues of all the fish species assayed contaminated iron and zinc into their respective gills, muscles and liver. The liver of the fish species had the highest concentration of iron followed by the gills while the muscle had the least. This agrees with Opaluwa *et al*. (2012) on heavy metals concentration in fish and sediments of

Uke stream and Ekelemu and Okoro (2020) in the study of bioaccumulation of heavy metals in fish species in the lower Niger River at Illah, Delta State, Nigeria. Comparing among the four fish species studied, the level of Fe accumulated in their gills is in this order *Clarias gariepinus* > *Bagrus bajad*>*Lates niloticus*>*Coptodon zilli*. The result is traceable to their feeding habits, habitat (benthic or pelagic) and the multiple uses of gills, the higher mean value of Fe concentration recorded in the liver of *Clarias gariepinus* compared to other species could be attributed to its benthic habitat that has direct contact with sediment and feeding/habit. Eneji *et.al.(*2011) in the study of bioaccumulation of heavy metals in fish organs from river Benue also reported that differences in the levels of accumulation in different organs of fish can primarily be attributed to the differences in the physiological role of each organ, other factors such as regulatory ability, behaviour and feeding habits may also play a significant role in the accumulation differences noticed in the different organs. Also, the chemical nature of the metal ionic strength and pH tends to be a major variable in the accumulation process. In acidic conditions, there are enough hydrogen ions to occupy many of the negatively charged surfaces and little space is left to bind heavy metals, hence more heavy metals remain in the soluble phase. The least mean value of iron was recorded in *Coptodon zilli* liver which agrees with Ekelemu and Okoro (2020). This study also revealed the presence of Fe in the muscle following the above concentration trend which agreed with the work of Eneji *et al.* (2012). The study revealed that the mean concentration of Fe found in the gills of all four fish species exceeded WHO (2011) set limit of 5.0mg/100g. *Clarias gariepinus* muscle recorded the highest value of 5.21 mg/100g while *Lates niloticus* recorded the least value of 3.54 mg/100g.The concentration fell below WHO (2011) limit.

Zinc concentration in fish tissues was below permissible limit WHO (2011). Eneji *et al. (*2011) reported higher values of zinc concentration in fish tissues in river Benue and Yehia and Sebaee (2012) recorded higher zinc concentration in fish tissues in Rosetta branch of river Nile, Egypt. The results indicated higher zinc concentration in fish tissue in dry season compared with wet season which could be as a result of concentration effects. *Clarias gariepinus* liver accumulated the highest mean value of 4.14mg/100g followed by *Bagrus bajad* liver,3.33 mg/100g, then *Coptodon* zilli liver 2.75 mg/100g.The organ with the least mean concentration was *Coptodon* muscle, 0.55 mg/100g. The trend for BAF for zinc in liver of the species in this study is *Clarias gariepinus* liver>*Bagrus bajad* liver>Copton zilli liver >*Lates noliticus* liver, 82.8,76.6,55.5 and 55 respectively. The result is due to the fact that target organs are metabolically active, hence can accumulate heavy metals in higher levels. This agrees with results in both the gills and intestine of *Coptodon zilli* and *Clarias gariepinus* from river Benue, Eneji *et.al*. (2011). Zinc is an essential trace element that is easily bioaccumulated by aquatic life, however it is toxic at levels above permissible limits.

CONCLUSION

The study clearly indicates bioaccumulation of heavy metals in different tissue organs of fish species studied in the lake. The mean concentration of iron and zinc in different organs followed a particular trend (liver>gills>muscle) in the four fish species studied. Concentration of iron exceeded the acceptable limits for consumption WHO (2011) in different tissue parts of all fish species, while Zn is within the permissible limits in both the gills and muscle tissues (all species) with the exception of the liver, this however calls for effective management of this valuable lake resource. Season has effect on the concentration of both Fe and Zn (raining season concentration higher than dry season). Shiroro lake should be assessed regularly in terms of heavy metals deposits occasioned by indiscriminate use of fertilizers, pesticides, herbicides, petrol discharge by merchants at Zumba market. Consumers of fish and fish products should be advised to concentrate on eating the muscle which is less contaminated, especially *Clarias gariepinus* and *Lates niloticus* (that are the most sorted for) whose livers are prone to heavy metals accumulation. Further research should be carried out on the health hazards associated with consumption of liver of *Clarias gariepinus* from Shiroro Lake.

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REFERENCES

American Public Health Association (APHA) (2015). Standard methods for the examination of water and waste water.15th edition Washington D.C pp 119.

American Public Health Association (APHA) (1995). Standard methods for the examination of waste water, 4th edition Washington D.C pp 1007.

Canli, M. and Atli,G. (2003).The relationship between heavy metal Levels of heavy metals (Cd, Cr,Cu,Fe,Pb,Zn) levels and the size of six Mediterranean fish species. *Environmental pollution* 121:129-136.*http;//dx.doi.org/10.1016/s0269-7491(02)00194-X*

Ekeanyanyu, C.R., Ogbuinyi, C. A. and Etienajirhevwe, O. F. (2010).Trace-metals distribution in fish tissues, bottom sediments and water from Okumeshi river in Delta State, Nigeria. *Ethiopian Journal of Environmental studies and Managemen*t.3 (3):12-17.

Ekelemu, J. K., and Okoro, K.O. (2020). Bioaccumulaton of heavy metals in five fish species in the lower Niger River at Ilah, Delta State. *Nigerian Journal of Fisheries* .17(1): 1941pp

Eneji, I.S., Sha'Ato, R., and Annune, P.A.,(2011).Bioaccumulation of heavy metals in fish (Tilapia zilli and Clarias gariepinus) organs from River Benue, North-central Nigera. *Pak. Anal. Environ. Chem.*12 (1 & 2): 25-31.

Eneji, I. S., Sha'Ato, R., and Annune, P. A. (2012).An assessment of heavy metals loading in River Benue in the Makurdi metropolitan Area in Central Nigeria. E*nvironmental monitoring and assessment*184 (1): 201-207.

Food and Agricultural Organization (FAO) (2017). Voices of the Hungry. In: FAO (On line). {cited 24 July,2017}.www.fao.org/in-action / voices –of-the Hungry./

Kigbu, A.A. and Annune, P.A. (2019). Assessment of Heavy Metals Concentration in Water, Gills, Muscle and Liver of *Oreochromis niloticus* in Amba Dam, Lafia Local Government Area, Nasarawa State, Nigeria. Proceedings of the 34th Annual Conference of Fisheries Society of Nigeria. pp 347-351

King, R.P. and Jonathan, G.E. (2003). Aquatic environmental perturbations and monitoring, African experience, USA pp 204-206.

Nguyen, H.L., Leemakers, M,Osan,J, Toroks,S and Baeyens, W. (2005).Heavy metals in Lake Balaton, water column, suspended matter, sediment and biota. S*ci. Total Environ*. (340) 213-230

Ojutiku, R.O., Habibu, S., Kolo, R.J. and Oyero, J.O. (2016). Assessment of physico-chemical parameters of River Kaduna and College of Agriculture and Animal Science Dam, (CAAS) Kaduna, Nigeria. Ethiopian. *Journal of Environmental Studies & Management*.9 (6):691-699.

Olaosebikan, B.D and Raji,A. (1998) . Field Guide to Nigerian Freshwater Fishes. Federal College of Freshwater Fisheries Technology, New Bussa, Nigeria 106 pp

Opaluwa, O.D., Aremu, M.O., Ogbo, L.O, Magaji, J.I., Odiba, I.E., and Ekpo, E.R. (2012). Assessment of heavy metals in water, fish and sediments from Uke stream, Nasarawa State, Nigeria. *Current World Environment,* 7(2):213-220.

Suleiman, Y. M and Ifabiyi, I.P. (2015).The role of rainfall variability in reservoir management at Shiroro hydropower dam, Nigeria. *Momona Ethiopian Journal of Science,* 7910:55-65

World Health Organization (WHO) (2011). Guidelines for drinking water quality (ii): Health criteria and supporting information, WHO, Geneva, Switzerland. pp 90-102 Google Scholar.

Yehia, H.M and Sebaee, E.S. (2012). Bioaccumulation of heavy metals in water, sediment and fish (Oreochromis niloticus and Clarias anguillaris) in Rosetta branch of the river Nile, Egypt. *African Journal of Biotechnology*.11 (7):14201-14216.

Yusufu, F. O. (2023). Heavy metal composition, dynamics and their bioaccumulation in selected commercial fish species in Shiroro lake, Nigeria, PhD Thesis, Federal University of Technology, Minna, 4 pp

EFFECTS OF DIETARY SUPPLEMENTATION LEVELS OF TIGER NUT (*Cyperus esculentus*) SEED ON GROWTH, SURVIVAL AND REPRODUCTIVE INDICES OF *Clarias gariepinus* BROODSTOCK

***[1]OLUSOLA, S. E., [2]A. O. ADENIJI, [1]F. O. AGBEBI, [1] O. V. AYEBIDUN AND [1]F. D. AMULEJOYE**
[1]Department of Fisheries and Aquaculture Technology, School of Agriculture, Food and Natural Resources, Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria.
[2]Department of Biological Sciences (Fisheries and Aquaculture Programme), School of Science, Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria.
*Corresponding author: se.olusola@oaustech.edu.ng; belloolus@yahoo.com, +2348034110139

ABSTRACT
The dietary effect of Cyperus esculentus seed powder was examined on the growth performance, survival and reproductive indices of Clarias gariepinus. Eighty (80) male and female catfish broodstock (400±0.00g) were obtained for the experiment, fed twice daily at 3% body weight for 56 days. Five diets with crude protein of 45% were formulated with different inclusion levels of C. esculentus seed powder; Control, TNSM 2 (0.5), TNSM 3 (1.0), TNSM 4 (2.0), and TNSM 5 (3%). Phytochemical screening, water quality, growth performance and reproductive indices were measured using standard methods. Phytochemical screening of C. esculentus revealed the presence of saponins, flavonoids, protein, tannins, steroids, phenol and glucosinolates while alkaloids were not detected. The values of temperature, pH and dissolved oxygen recorded were within the acceptable limits for culture water. The treated groups had better values in weight gain, percentage weight gain, and specific growth rate and feed conversion ratio when compared to the control diet. The reproductive indices show a significant (P<0.05) increase in the treated groups than the control. This result revealed that dietary inclusion of C. esculentus seed powder enhances growth and improves fertility in Clarias gariepinus which will improve the quantity of its seed production.

Keywords: *Cyperus esculentus,* Growth performance, Reproductive indices, *Clarias gariepinus*; Survival

INTRODUCTION

Aquaculture is a fast-growing food-producing sector and developed as an important component of food security in Nigeria and the world at large (Ibrahem *et al.*, 2010). It has several economic importance making the practice a source of food, majorly in form of fish supply. The population of Nigeria is on the rise and there is a corresponding demand for fish consumption (Chukwu, 2006). Nigeria, like most third-world countries, is not able to meet its animal protein requirement for meat, fish and their respective products. This is traceable to fish production which has fallen below expectation (Akinrotimi, 2007) and yet fish plays a significant part in the world protein supplies, particularly in developing countries (Bolaji *et al*., 2011). The African catfish, *C. gariepinus* is a major cultivated fish of high commercial value in Nigeria and is ideal for captive breeding (Adesulu, 2007). It is of great importance to the sustainability of the aquaculture industry in Nigeria. This is because it constitutes an excellent food fish known for its resistance to diseases, high growth rate, resistance to handling and stress, and ability to tolerate a wide range of environmental parameters but many limitations are associated with fry production and the development of better broodstock.

The development of fish seed production has been identified as a rational way of augmenting the dwindling fish supply from the capture fisheries (Dada and Fagbenro, 2008). The ever-growing demand for the seed of *C. gariepinus* calls for more production of high-quality milt which could be used to fertilize the eggs in the hatchery. It has been shown by several studies that medicinal plants can influence fertility in man, animals and fish (Olusola *et al.*, 2021). *Cyperus esculentus,* known as tiger nut, is a crop of the sedge family, widespread across much of the world. Tiger nut is also found to be a cosmopolitan perennial crop of the same genus as the papyrus plant and it is widely distributed in the temperate zones within South Europe as its probable origin and has become naturalized in Ghana, Nigeria and Sierra Leone. The seed of *Cyperus esculentus* is edible, with a slightly sweet nutty flavour. It supplies the body with enough quantity of vitamin E, vitamin C, zinc and quercetin essential for fertility in both men and women and it has been found to stimulate sexual arousal and also improve sexual performance (Dada, 2012) which may have similar effects in fish.

Many studies have shown that antioxidants can enhance fertility either directly or indirectly and most plants rich in antioxidants have the tendency to increase sperm count, and motility and enhance the production of oestrogen and testosterone (Yeganeh *et al.*, 2017). *Cyperus esculentus* has antioxidant steroids present in a quiet number, therefore, a high possibility that *C. esculentus* can promote fertility, but there is little or no documentation on its utilization on indigenous fish species such as *C. gariepinus*. Hence, this study was therefore carried out to investigate the effect of the dietary supplementation of *C. esculentus* seed powder on the growth, survival and reproductive indices of male and female *C. gariepinus* broodstock.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Research and Teaching Farm, Olusegun University of Science and Technology, Okitipupa, Nigeria. The experiment lasted for eight weeks (56 days) between May-June, 2021.

Plants Collection, Identification and Preparation

Tiger nuts were obtained from Mokola Roundabout, Ibadan North Local Government Area of Oyo State, Nigeria. They were authenticated at the Department of Biological Sciences (Botany Programme) of Olusegun Agagu University of Science and Technology, Okitipupa. Tiger nuts were washed with sterile distilled water and air-dried at 25℃ for two weeks after which it was grounded into a fine powder and stored until required.

Collection and Acclimatization of Experimental Fish

Eighty (80) *C. gariepinus* broodstock (40 males and females, mean weight 400 ± 0.01g) were procured from a commercial Farm in Okitipupa, Ondo state, Nigeria. The *C. gariepinus* were acclimatized for two weeks in a fibre holding tank at the Research and Teaching Farm, Ondo State University of Science and Technology, Okitipupa. During this period, they were fed with commercial diets (Coppens, 6 mm) of 40% crude protein twice daily at 3% body weight.

Diets Preparation

The ground tiger nuts at different inclusion levels of 0. 0.5, 1.0, 2.0 and 3.0 with feed ingredients such as fishmeal, soya bean, millet, maize, blood meal, Di-calcium phosphate, salt, vitamin premix and vegetable oil were mixed using manual methods to formulated 45% crude protein. Each diet mixture treated separately was extruded through a 6 mm mincer pelleting machine to form a noodle-like suitable size for the adult *C. gariepinus*. The pelleted diets were sun-dried, packed in labelled polythene bags and stored until required (Table 1).

Table 1: Gross and proximate composition of the experimental diets (g/100g)

	CONTROL	TNSM 2 (0.5%)	TNSM 3 (1.0%)	TNSM 4 (2.0%)	TNSM 5 (3.0%)
Blood meal (80% CP)	23.19	23.19	23.19	23.19	23.19
Fishmeal (72% CP)	11.59	11.59	11.59	11.59	11.59
Soybean (42% CP)	23.19	23.19	23.19	23.19	23.19
Millet (18% CP)	17.02	17.02	17.02	17.02	17.02
Yellow maize (10% CP)	17.02	17.02	17.02	17.02	17.02
Di calcium phosphate	2.00	2.00	2.00	2.00	2.00
Salt	1.00	1.00	1.00	1.00	1.00
Vegetable oil	2.00	2.00	2.00	2.00	2.00
Vit – min premix	3.00	2.50	2.00	1.00	-
Tiger nut seed	-	0.50	1.00	2.00	3.00
Total	100.00	100.00	100.00	100.00	100.00
***Proximate composition (% DM)					
Moisture	5.86	5.47	5.52	5.41	5.54
Crude protein	45.01	45.00	45.01	45.06	45.03
Crude lipid	13.46	13.33	13.87	13.25	13.56
Ash	10.15	11.56	11.59	11.87	11.78
NFE	25.52	24.64	24.01	24.41	24.09

** Vit-premix for vitamin and minerals premix. Each 2.kg of premix contain; 12.5 million international unit (MIU); D_3, 2.5 MIU;E, 40g; K_3 2g; B1,5.5g;BB6,5g; Niacin 55g; Calcium Pantothenate 11.5g; Chlorine chloride 500g; Folic acid, Biotin,0.08g;Manganese, 120g; Iron, 100g; Zinc, 80g, Copper,8.5g; Iodine, 1.5g;Cobalt,0.3g;Selenium, 0.12g; Anti-oxidant, 120g. ** Determined using standard methods [AOAC 2005). All samples were analysed in triplicates. NFE= Nitrogen Free Extract = 100 - (Crude protein + Crude fiber + Lipid content + Moisture content + Ash), *** Proximate composition of experimental diet using standard methods of AOAC, (2005).

Experimental Set-up

Water was sourced from the Research and Teaching Farm borehole and was filled to a depth of 1.2m into five (5) fibre holding tanks and replicated twice. Eighty *C. gariepinus* were stocked into the 10 fibre holding tanks containing eight (8) *C. gariepinus* broodstock (4 males and 4 females) per treatment tank. The diets were assigned to the tanks as designated and were fed at 3% body weight in two equal portions at 08:00hours – 09:00hours and 17:00hours – 18:00hours for 56 days. All fish were removed from each fibre holding tank every fourteen days and batch-weighed, their average weights were recorded and the daily amount of feed for each tank was readjusted accordingly.

Water Quality Parameters

Water quality parameters namely temperature, pH and dissolved oxygen concentration were monitored daily throughout the study period using a mercury-in-glass thermometer, pH meter (Hanna H198106 model) and dissolved oxygen meter (JPP-607 model) as described by APHA (2005).

Biological Evaluation

Weight gain = final body weight-initial body weight

$$\text{Weight gain (\%)} = \frac{\text{Final body weight} - \text{initial body weight}}{\text{Initial body weight}} \times 100$$

Increase in standard length (CM) = L2-L1

Where L2 = Final standard length; L1 = Initial standard length

$$\text{Specific growth rate (SGR)} = \frac{100\ (\text{log final body weight} - \text{log initial body weight}}{\text{Time (days)}}$$

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Dry weight of feed fed (g)}}{\text{Fish weight gain (g)}}$$

$$\text{Survival rate (\%)} = \frac{\text{Initial Number of Fish Stocked} - \text{Mortality}}{\text{Initial Number of Fish stocked}} \times 100$$

Condition factor (k) = 100W/L3

Where: W= weight of fish (g); L=standard length (cm)

$$\text{Nitrogen metabolism} = \frac{(0.549)\ (a+b)h}{2}$$

Where, a = Initial mean weight of fish; b= final mean weight of fish; h= experimental periods in days (Bello *et al.*, 2012).

Artificial Propagation

Two (2) male and female spawners from each treatment were taken and used for artificial propagation techniques- hormone administration, stripping, fertilization and incubation as described by Olusola *et al*., (2022).

Evaluation of Milt Quality

At the end of the feeding trials, 2 males were randomly selected per dietary treatment and were weighed, killed and dissected to remove the testes to determine milt volume, motility duration, and milt counts and this was done as described by Olusola *et al*., (2021)

Ovary Weight and Egg Size Estimation

At the end of the feeding trials, 2 females were randomly selected per dietary treatment and weighed, killed and dissected to remove the ovaries. The ovaries were carefully weighed after removing excess water on filter paper and counted, the number of eggs per l g and then calculated the total number of eggs. The total number of eggs per ovary was derived by multiplication by the factor; of total weight/10 g. Three (3) fresh eggs were randomly selected per dietary treatment and were used for egg diameter (mm) measurement. For the pear-shaped eggs, the mean diameter of the long and short axes was taken as the diameter of the oocyte (Salau *et. al.,* 2012).

Belly Diameter and Gonado-Somatic Index (GSI)

Two (2) female broodstock were randomly collected from each treatment and determined their belly diameter as follows: Belly diameter =Length of horizontal axis from the ventral region of the pectoral fin to the vent region + belly width. The gonado-somatic index (GSI) was computed according to Olusola *et al*., (2021) as;

$$\text{GSI} = \frac{\text{Gonads weight (g)}}{\text{Fish weight (g)}} \times 100$$

Estimation of fecundity, fertilization, and hatchability

One (1) gramme each of egg was measured into ten (10) different bowls which were labelled accordingly. The eggs were fertilized with 1ml of milt from each dietary treatment. The percentage of an egg fertilized as well as the percentage number of eggs hatched and the percentage of survival were computed according to the method described by Ayinla and Akande (2010):

$$\text{Relative fecundity} = \frac{\text{Total number of eggs}}{\text{Bodyweight}}$$

$$\text{Fertilization rate} = \frac{\text{No of the fertilized egg in sample}}{\text{Total no of egg in sample}} \times 100$$

$$\text{Hatching rate} = \frac{\text{No of hatched eggs in a sample}}{\text{Total no of eggs in a sample}} \times 100$$

Statistical Analysis

The values were recorded as a mean ± Standard Error. One-way Analysis of variance (ANOVA) was performed using SPSS 22 for the window software package at ($P < 0.05$) significance level. Significantly different means were compared using Duncan's multiple range test.

RESULTS

Determination of Phytochemicals in Tiger Nuts

The phytochemical screening of tiger nut revealed the presence of saponins, flavonoids, protein, tannins, steroids, phenol and glucosinolates while alkaloids were not detected. The value of these metabolites was low (+), moderate (++), and absent (-) as shown in table 2.

Table 2: Phytochemical screening of tiger nuts

SAMPLES	PHYTOCONSTITUENTS	RESULTS
	Saponins	++
	Flavonoids	++
	Phenol	++
	Alkaloids	-
Tiger nuts	Tannin	+
	Glucosamines	+
	Steroid	++
	Protein	+

Water Quality in culture tanks of *C. gariepinus* fed tiger nut seed supplemented diets for 56 days

The result of the mean water quality of this study revealed that the pH range between 5.6 – 6.3, dissolved oxygen ranged between 5.95 – 6.19 mg/l and the temperature ranged between 27 – 30^{0}C. The highest temperature was recorded in control and lowest in the treated groups except TNSM $_2$ (0.5%). Highest pH was recorded in TNSM $_3$ (1.0%) and lowest in TNSM $_5$ (3.0%) while highest dissolved oxygen was recorded in TNSM $_4$ (2.0%) and lowest in control. These values were within the acceptable limits for culture water (Table 3).

Table 3: Mean water quality of *Clarias gariepinus* fed tiger nut seed supplemented diets for 56 days

	Temperature (^{0}C)	pH (-)	Dissolved Oxygen (mg/l)
Control	30	6.0	6.10
TNSM $_2$ (0.5%)	28	6.1	6.25
TNSM $_3$ (1.0%)	27	6.3	6.33
TNSM $_4$ (2.0%)	27	5.9	6.51
TNSM $_5$ (3.0%)	27	5.6	6.39

Growth Performance and Nutrient Utilization of *C. gariepinus* fed with Dietary Supplementation of Tiger nuts for 56 days

The growth performance and nutrient utilization in terms of body weight gain, feed conversion ratio, percentage weight gain, nitrogen metabolism and specific growth rate were presented in Table 4. The highest weight gain was recorded in TNSM $_4$ (2.0%) and lowest recorded in the control. The highest feed conversion ratio was recorded in the control and the lowest recorded in TNSM $_4$ (2.0%), nitrogen metabolism and specific growth rate ere highest in the TNSM $_4$ (2.0%) and lowest in the control. while survival rate was 100% in all the treatment groups. There was no significant difference ($P > 0.05$) in the initial body weight and survival rate among the fish fed on a diet containing tiger nuts based diets and the control

Table 4: Growth Performance and Nutrient Utilization of *Clarias gariepinus* fed with Tiger nuts for 56 days

PARAMETERS	CONTROL	TNSM $_2$ (0.5%)	TNSM $_3$ (1.0%)	TNSM $_4$ (2.0%)	TNSM $_5$ (3.0%)
IBW (g)	400.00±0.01^a	400.00±0.00^a	400.00±0.01^a	400.00±0.00^a	400.00±0.00^a
FBW (g)	760.00±2.00^b	780.00±1.86^c	780.00±1.87^c	790.00±2.01^d	690.00±0.22^a
WG (g)	360.00±0.01^b	380.00±0.02^c	380.00±0.03^c	390.00±0.07^d	290.00±0.01^a
PWG (%)	90.00±0.05^b	95.00±0.08^c	95.00±0.04^c	97.50±0.03^d	72.50±0.01^a
SGR (g)	0.50±0.02^b	0.52±0.01^c	0.52±0.00^c	0.53±0.01^d	0.43±0.02^a
FCR	2.00±0.03^c	1.72±0.01^b	1.74±0.03^b	1.61±0.04^a	2.21±0.05^d
SR (%)	100.00±0.00^a	100.00±0.00^a	100.00±0.00^a	100.00±0.00^a	100.00±0.00^a
NM (g)	17831.52±30.74^b	18138.96±20.70^c	18138.96±28.00^c	18292.68±26.42^d	16755.48±27.05^a
PPI	642.86±3.05^b	698.57±4.59^c	698.57±4.91^c	696.43±5.09^d	517.86±2.27^a

Keys: IBW= Initial Body Weight, FBW= Final Body Weight, WG=Weight Gain, PWG = Percentage Weight Gain, SGR = Specific Growth Rate, FCR = Feed Conversion Ratio, SR = Survival Rate, NM = Nitrogen Metabolism, PPI = Production Performance Index, the above values are mean duplicate data, mean values in each row with similar superscript are not significantly different (P > 0.05).

The reproductive performance of male *C. gariepinus* Fed with Dietary Supplementation of Tiger nuts for 56 days

The result of males fed with tiger nuts dietary supplements revealed that the highest weight of the male was recorded in TNSM $_4$ (2.0%) and lowest in TNSM $_5$ (3.0%). The highest Weight of testis was recorded in TNSM $_4$ (2.0%) and lowest in control. The highest milt volume was recorded in TNSM $_3$ (1.0%) and lowest in TNSM $_2$ (0.5%) and TNSM $_5$ (3.0%) while the highest sperm counts was recorded in TNSM $_4$ (2.0%) and lowest in the control (Table 5).

Table 5: Reproductive performances of male *C. gariepinus* fed different graded levels of tiger nut seed for 56 days

PARAMETERS	CONTROL	TNSM $_2$ (0.5%)	TNSM $_3$ (1.0%)	TNSM $_4$ (2.0%)	TNSM $_5$ (3.0%)
Weight of male (g)	760.00±2.00^b	780.00±1.86^c	780.00±1.87^c	790.00±2.01^d	690.00±0.22^a
Weight of testis (g)	2.50±0.50^a	4.00±0.00^a	3.00±0.20^a	4.00±0.00^a	3.50±0.50^a
Milt volume (ml)	1.00±0.01^a	0.60±0.03^a	2.20±0.30^b	1.20±0.08^a	0.60±0.05^a
Motility duration (s)	30.00±0.04^a	38.00±0.06^{bc}	50.00± 0.70^d	42.00±0.09^c	32.00±0.00^{ab}
Sperm count (10^4spm/ml)	399000.00±2000^a	615600.00±1000^e	783090.00±1300^d	512870.00±1200^c	458976.00±1800^b

Key: The above values are mean duplicate data, mean values in each row with similar superscript are not significantly different (P > 0.05).

The reproductive performance of female *C. gariepinus* Fed with Dietary Supplementation of Tiger nuts for 56 days

The results of females *C. gariepinus* revealed highest weight of ovary, number of eggs and relative fecundity in the treated group, TNSM $_5$ (100%) and TNSM $_4$ (75%) respectively and lowest in the control. Gonado somatic index and hatchability was highest in TNSM $_5$ (100%) and lowest in control. fertilization was highest in TNSM $_3$ (50%) and lowest in control. the belly diameter was highest in control and lowest in TNSM $_3$ (50%) (Table 6).

Table 6: Reproductive performances of female *C. gariepinus* fed different graded levels of tiger nut seed for 56 days

PARAMETERS	CONTROL	TNSM $_2$ (25%)	TNSM $_3$ (50%)	TNSM $_4$ (75%)	TNSM $_5$ (100%)
Weight of female g)	760.00±2.00^b	780.00±1.86^c	780.00±1.87^c	790.00±2.01^d	690.00±0.22^a
Belly diameter (mm)	11.20±2.28^a	10.55±3.05^a	9.50±3.10^a	10.90±2.90^a	9.75±2.25^a
Weight of ovary (g)	53.00±1.00^a	103.00±6.34^d	87.00±1.50^b	95.00±2.56^c	141.00±3.20^e
Weight of eggs (g)	165.00±8.70^c	124.00±3.02^b	86.00±0.08^a	130.00±4.61^b	87.00±0.01^a
Size of eggs (g)	0.13±0.02^b	0.10±0.00^a	0.13±0.01^b	0.15±0.03^b	0.10±0.01^a
Relative fecundity	46.20±0.02^a	112.61±1.08^d	101.46±0.34^c	122.46±2.35^e	71.90±0.08^b
Gonado-somatic index	7.10±0.02^a	17.17±0.12^d	15.43±0.06^c	10.96±0.04^b	18.66±0.09^e
Number of eggs (g)	33768.00±1200^a	67568.00±2000^c	57072.00±4000^b	62320.00±3500^{bc}	92496.00±4300^d
Latency period (h0	11.40±0.02^a	13.12±0.04^b	11.45±0.01^a	11.46±0.00^a	13.40±0.04^c
Hatching time (h)	23.55±0.02^a	24.46±0.34^b	24.18±0.06^b	24.35±0.02^b	24.35±0.01^b

Hatchability (%)	62.50±0.88[a]	75.84±0.02[c]	75.84±0.00[c]	84.76±0.20[d]	88.96±0.40[e]
Fertilization (%)	62.07±2.00[a]	93.23±0.00[b]	95.42±0.02[b]	94.66±0.20[b]	93.14±0.00[b]

Key: The above values are mean duplicate data, mean values in each row with similar superscript are not significantly different (P > 0.05).

DISCUSSION

The result of the mean temperature, dissolved oxygen and pH recorded in this study were within the ranges that are considered to be good enough for the development of African catfish. This finding supports the report of Olusola and Olorunfemi, (2017) who observed a temperature range of 28- 30^{0}C, dissolve oxygen 6.02 – 7.08 mg/l and pH of 5.70 - 6.19 for *C. gariepinus* fed guava *(Psidium guajava)* leaves and drumstick (*Moringa oleifera)* leaves extracts supplemented diet. The phytochemical analysis revealed the presence of saponins, flavonoids, tannins, protein, steroids, phenol and glucosinolates in *C. esculentus.* Alkaloid was found to be absent in *C. esculentus*. This study was aligned with the report of Ani *et al*. (2021); Charles *et al.*, (2018) and Nwaoguikpe, (2010) who observed the presence of flavonoids, tannin, saponins, steroids, phenols and glucosinolates in *C. esculentus* These constituents may have been responsible for the positive influence of *C. esculentus* seed powder on growth and reproductive indices of *C. gariepinus* broodstock.

During the 56 days of feeding trials, all the treated groups except TNSM $_5$ (100%) had better values in weight gain, percentage weight gain, and specific growth rate and feed conversion ratio when compared to the control diet. The treated group, TNSM $_4$ (2.0%) had the best performance in terms of weight gain, percentage weight gain, specific growth rate, feed conversion ratio and nitrogen metabolism when compared to other treated groups. This result is in accord with Yeganah *et al*., (2017) who reported a better performance in weight gain, survival rate and specific growth in *Cichlasoma nigrofasciatum* of treated groups compared to the control diet, the result is also in agreement with Olusola *et al.* (2021) who report better performance in weight gain, specific growth rate, and feed conversion ratio in *C. garipienus* fed with *Datura stramonium* when compared to the control. It was observed in that the value obtained increases as the inclusion level increase, however, the value decreases at 3.0 % inclusion of tiger nut. The increase in the weight gain of the fish-fed treated groups could be attributed to the presence of growth-promoting constituents (Saponins and flavonoids) present in the diets. These properties could contribute to digestion and nutrient absorption with a subsequent increase in fish weight.

Also, this study observed that diets supplemented with tiger nuts had better values in motility duration, the weight of testes, sperm counts and milt volume compared to the control and there was a significant difference (P < 0.05) among the dietary groups except for the weight of testes. This result was in agreement with Olusola *et al.*, (2022) who reported a higher performance in weight of testes, sperm counts, motility duration and milt volume of C. gariepinus broodstock fed Cattle Stick (*Carpolobia lutea*) leaves when compared to the control diet. This finding also agrees with the report of Sharma *et al.* (2008) who also observed an increase in sperm counts with extract of *Anacyclus pyrethrum* in male rats. The increase in milt volume and sperm counts observed in *C. gariepinus*-fed diet supplemented with graded levels of *C. esculentus* could be linked to the presence of steroids, highly effective antioxidants capable of increasing testosterone production, a key hormone involved in milt quality and production.

The results of this study showed that increased ovary weight, gonado somatic index, fecundity, percentage fertilization, and hatchability of the eggs were better in the treated groups when compared to the control. The hatchability values obtained in this study increased as the inclusion levels of *C. esculentus* increased. Higher fecundity values were obtained in the fish fed with TNSM 4 (122.46) compared to the control (46.5). Similar results were also reported by Adeparusi *et al.* (2011) on the use of the medicinal herb *Kigelia africana* as a fertility enhancing agent for catfish *C. gariepinus.* Dada, (2012) also reported that *C. gariepinus* broodstock fed on *Mucuna prurien* diets supplemented exhibited improved reproductive performance than those fed with the control diet. The increase in the fecundity of *C. gariepinus* which was obtained in this study could be a result of the presence of flavonoids, glycosides and steroids in the plant which are potent antioxidants capable of increasing the production of oestrogen, the major hormone involved in the production and maturation of eggs in the ovaries.

The size of eggs was largest in TNSM 4 (0.15) and this affects the fertilization of the eggs. Some authors however opined that egg diameter is not a good indicator of egg and larval quality. Dada, (2012) reported that fish with lower egg size has high fecundity therefore, the importance of egg size has been difficult to ascertain because of conflicting results from various studies and because of problem in separating the effect of other factors such as age, strain, and nutritional status of the fish. The control had better hatching time compared to the treated groups. It was observed in the result that all the treated groups had higher gonadosomatic index (GSI) compared to the control diet with a significant difference ($P < 0.05$) among the dietary groups. This report was in accord with the result of Ekpo *et al*., (2018) who reported a high performance in relative fecundity, gonadosomatic index, mean egg diameter, and female ovary weight in *C, garipienus* of *Adenia cissampeloide* treated groups compared to the control. This also agrees with the findings of El-Sebaie *et al*. (2014). The presence of the phytochemical constituents of the plants such as saponins, alkaloids, terpenoids, flavonoids, etc., might have altered the biosynthetic processes underlying the growth and development of the fish and its ovaries in the treated groups in comparison with the control. These constituents may have been responsible for the positive influence of *C. esculentu*s on reproductive indices of *C. gariepinus* broodstock.

CONCLUSION

Viable sperm and eggs are essential components of any successful animal production operation and the success of the reproduction process is dependent on a supply of high-quality gametes. The present study, therefore, suggests that the inclusion of *C. esculentus* seed meal in the diet of *C. gariepinus* should be encouraged since there was a positive effect on the growth, survival and reproduction performance indices of female and male *C. gariepinus*. It is therefore concluded that the potency of *C. esculentus* has promising growth, survival and fertility enhancer instead of using synthetic drugs that are expensive and have a residual side effects on the organism. The inclusion of 2.0% of *C. esculentus* seed would enhance the growth performance, survival and reproductive indices in *C. gariepinus* broodstock in organic fish farming.

REFERENCE

0041desulu, E.A and Sydenham, D.H.J. (2007). The Freshwater Fishes and Fisheries of Nigeria. Macmillan Nigeria Publishers Ltd., Nigeria, 397 p.

Akinrotimi, O.A., Onunkwo, D.N., Cliffe, P.T., Ayanwu, P.E and Orokotan, O.O. (2007). The role of fish in the nutrition and livelihoods of families in Niger Delta. *Nigeria International Journal of Tropical Agriculture and Food System*, 1: 344 – 351.

Ani, A.O., Adelere, F.I., Sholotan, K.J and Nwaemeke, D.I. (2021). Mineral, Vitamin and Phytochemical Content of the Tiger nut. *World Journal of Applied Chemistry*, 6 (3): 36-40. DOI: 10.11648/j.wjac.20210603.12

Association of Official Analytical Chemists (2005). Association of official analytical chemists' official method of analysis (19th Edition) (K. Heltich Edition), Arlington, Virginia, 1:18-32.

Association of Public Health Analyst (2005). Standard method for examination of water and wastewater. 17th edition, American Public Health Association, Washington D.C.;1268.

Ayinla, O.A. and Akande, G.R. (2010). Growth response of *Clarias gariepinus* (Burchell 1822) on silage-based diets. NIOMR Technical. Nigerian Institute for Oceanography and Marine Research, Lagos.;19.

Bello, O.S, Olaifa, F.E and Emikpe B.O. (2012). The effect of Walnut (*Tetracarpidium conophorum*) leaf and Onion (*Allium cepa*) bulb residues on the growth performance and nutrient utilization of *Clarias gariepinus* juveniles. *Journal of Agricultural Science, Canada* Vol. 4 (12): 205 – 213

Bolaji, B.B, Mfon, T.U. and Utibe, D.I. (2011). Preliminary study on the aspects of the biology of snakehead Fish *Parachanna obscura* (Günther) in a Nigerian wetland. *African Journal of Food, Agriculture, Nutrition and Development*, 11 (2): 4708-4717

Charles, O.N., Essien, E.B and Patrick-Iwuanyawu, K.C. (2018). Studies on the phytochemical, proximate composition and biochemical properties of the combination of *Cyperus esculentus* (tiger nuts) and *Phoenix dactilyfera* (date fruit) flour on male albino Wistar rats, *Journal of Pharmacognosy and Phytochemistry,* 7(5): 1049-1054

Chukwu, L.O. (2006). Impact of Dam Construction on Fisheries Resources Conservation in Nigeria. Paper presented at the National Workshop on Prevention of obnoxious fishing practices and promotion of Responsible inland fishing Methods held at shiroro Hotel, *Minna, 13-19 Oct. 1996, 24pp.*

Dada, A.A. and Fagbenro, O.A. (2008). Catfish fingerlings production in Nigeria. *Proceedings of the 4th Annual Conference of School of Agriculture and Agricultural Technology,* Federal University of Technology, Akure. P. 107-110.

Dada, A. A. (2012). Effects of Garcinia kola seed meal on egg quality of the North African catfish, *Clarias gariepinus* (Burchell, 1822) broodstock. *African Journal of Food, Agriculture, Nutrition and Development*.;12:6447-6459.

Ekpo, P.B. Uno, U.U. Okolo, C.M, Agu, R.B. and Onwudike, C.F. (2018). Acute toxicity of *Adenia cissampeloides* in farmed African Catfish (*Clarias gariepinus*). *Annual Research and Review in Biology*, (5):1-5.

El-Sebaie, H. E. Mahmoud, N. H. Mahmoud, H. I. and Saad, Y. M. (2014). Biological performance of *Pterophyllum scalare* larvae fed on Artemia and artificial diet. World *Journal of Fish and Marine Sciences*, 6, 289–294.

Ibrahem, M.D., Fathi, M., Mesalhy, S. and Abd El-Aty, A.M. (2010). Effect of dietary supplementation of insulin and vitamin C on the growth, haematology, innate immunity, and resistance of Nile tilapia (*Oreochromis niloticus*). *Fish Shellfish Immunol., 29*:241- 6

Nwaoguikpe, R.N. (2010). The phytochemical, proximate and amino acid compositions of the extracts of two varieties of tiger nut (*cyperus esculentus*) and their effects on sickle cell haemoglobin polymerization, *Journal of Medicine and Medical Sciences*, 1(11): 543-549

Olusola, S.E and Olorunfemi, B.V. (2017). Bioproductive effects of *Clarias gariepinus* fingerlings fed guava *(Psidium guajava)* leaves and drumstick (*Moringa oleifera)* leaves extracts supplemented diet. *Journal of Applied and Tropical Agriculture*, 22 (2): 156- 165

Olusola, S.E., Aladegboye, C.A, Amulejoye, F.D and Fatoba, T.A. (2021). Assessment of Dietary Supplementation of Thorn Apple *Datura stramonium* Seed on Growth and Reproductive Performance of *Clarias gariepinus* Broodstock. *Nigeria Journal of Animal Production*, 48(6):56-64. https://doi.org/10.51791/njap.v48i6.3277

Olusola, S.E., Aladegboye, C.A., Amulejoye, F.D and Ayanboye, A.O. (2022). Dietary effects of supplementation of Cattle stick (*Carpolobia lutea)* leaves on growth and reproductive indices of male and female *Clarias gariepinus* broodstock. *Aceh Journal of Animal Science, 7 (2): 28- 33 DOI: 10.13170/ajas.7.2.23679*

Salau, R.B. Ndamitso M.M., Paiko, Y.B., Jacob, J.O., Jolayemi, O.O., and Mustapha, S. (2012). Assessment of the proximate composition, food functionality and oil characterization of mixed varieties of *Cyperus esculentus* (tiger nut) rhizome flour. *Continental J. Food Science and Technology* 6 (2): 13 – 19.

Sharma, V. Thakur, M. Chauhan, N.S and Dixit, V.K. (2008). Evaluation of the Anabolic, aphrodisiac reproduction activity of *Anacyclus pyrethrum* in Male Rats. *Scientia Pharmaceutical*. 200:1-13.

Yeganeh, S., Sotoudeh, A and Movaffagh, A.N. (2017). Effects of *Tribulus terrestris* extract on growth and reproductive performance of male convict cichlid (*Cichlasoma nigrofasciatum*). *Turkish Journal of Fisheries and Aquatic Sciences*, 17: 1003–1007

GENETIC DIVERSITY OF TILAPIA IN NIGERIA USING AVAILABLE COI SEQUENCE IN THE GENE BANKS

[*1]MOJEKWU T. O. AND [2]N. M. ACHILIKE
[1]*Biotechnology Department, Nigerian Institute For Oceanography and Marine Research*
[2]*Aquaculture Department, Nigerian Institute For Oceanography and Marine Research*
3 Wilmot Point Road, off Bar beach Bus stop. P.M.B 12729, Victoria Island, Lagos, Nigeria
*Corresponding Author: tonyystone@yahoo.com, +2348033567661

ABSTRACT
Tilapia importance in global aquaculture and fisheries has motivated the study and assessment of their genetic diversity in Nigeria. In this article, attempt was made to retrieved all available mitochondrial cytochrome c oxidase subunit I gene (COI) sequences of tilapia species from Nigeria deposited in BOLD and NCBI, to quantify their available DNA barcoding information. It appears output of tilapia species barcoding studies in Nigeria were not much as we got only 112 hits. Maximum likelihood analyses of the sequences with three tilapia reference genomes and three distant outgroups (669 bp fragment; N=112+3+3) showed two groups of Nile tilapia Oreochromis niloticus, identification of some unidentified Tilapia spps and Oreochromis as Coptodon camerunensis, Coptodon dageti and Oreochromis aureus, presesnce of Blue tilapia Oreochromis aureus in both species of O. niloticus and Sarotherodon galilaeus groups independently. These species are readily utilized for aquaculture in Nigeria and could escape from farms into the wild due to poor waste management or flooding. Hence, this may explain why the BLAST search identified an unplaced sequence from Ondo, Nigeria as Coptodon camerunensis (99.2%), a strain endemic to Northern Cameroonian rivers. However, O. niloticus individual from River Benue could be pure based on placement with its genome. Considering the limitations of mtDNA, we recommended an exome gene capture approach in addressing issues of introgressive hybridization, for better-informed conservation of tilapia pure stocks.

KEYWORDS: Cichlids, GenBank, Introgression, Mitochondrial DNA, Phylogenetic, Geographical regions.

INTRODUCTION

Tilapias are freshwater fish of Cichlidae family native to Africa and middle East. They are widely distributed across Africa except Atlas Mountains and Southwest Africa, (McAndrew 2000). There are 76 reported tilapia species in Africa (Philippart and Ruwet 1982; Adesulu 1997), however, 52 tilapia species of the Cichlidae family which includes 32 *Oreochromis*, 13 *Sarotherodon*, and seven *Tilapia* species were suggested by Fishbase (Froese and Pauly 2018). Nigeria is one of the leading producers of farmed tilapias in Africa, with Egypt topping the chain (Adesulu 1997; El-Sayed 2006; Fagbenro *et al*., 2010). There are about six species of tilapia commonly used for aquaculture, namely, *Oreochromis niloticus*, *O. aureus*, *Sarotherodon galilaeus*, *S. melanotheron*, *Tilapia zillii and Tilapia. guineensis (*Adesulu and Sydenham 2007; Idodo-Umeh 2003).

Their utilization in aquaculture can also result in the taxonomic classification confusion of tilapia among researchers (Dunz and Schliewen 2013). This is because farmed populations usually colonize non-native water catchments either by intentional introduction or escape from the farm due to poor disposal management (Ford *et al.,* 2015; Syaifudin *et al.,* 2019; Wu and Yang 2012; Shechonge *et al.,* 2019). This can lead to hybridization, habitat alteration, and ecological competition that threatens native species (Bbole *et al.,* 2014; Canonico *et al*., 2005; Deines *et al.,* 2014; Firmat *et al*., 2013; Mwanja *et al*., 2012). Flooding is another major event that can destroy farms, cause the overflowing of rivers, and homogenize different species (Askew 1999; Odufuwa *et al.,* 2012; Umar and Gray 2022). In Nigeria, flooding has been happening and causing overflow of major river systems with devastating impact across Nigeria (Chukwu 2014; Horsfall *et al.,* 2023; Ishaya *et al.,* 2023). This long time level of flooding over several generations of species, questions the purity of any inland aquatic species in Nigeria or Africa. This could lead to introgressive hybridization and taxonomic confusion among researchers, as observed by the recent changes of names of some Tilapia species; *Tilapia dageti* (Thys van den Audenaerde 1971), *Tilapia guineensis* (Günther 1862), *Tilapia mariae* (Boulenger, 1899) and *Tilapia zillii* (Gervais 1848) reclassified as *Coptodon dageti* (Thys van den Audenaerde 1971), *Coptodon guineensis* (Günther 1862), *Pelmatolapia mariae* (Boulenger 1899) and *Coptodon zillii* (Gervais 1848), respectively. Hence, there is need for proper molecular taxonomic assessment of tilapia species diversity in Nigeria.

DNA barcoding is a short fragment that is easily used to identify species by comparing it to a reference library of DNA sequences for a given taxonomic group. The standard tool for DNA barcoding mostly used to differentiate species and detect diversity in animals is the mitochondrial genes such as cytochrome c oxidase subunit I gene (COI) (Kadarusman *et al.,* 2012; Kakioka *et al.,* 2018). In Nigeria DNA barcode library has been employed to study the taxonomy of Nigerian fishes (Nwani *et al.*, 2011; Nwakanma *et al*., 2015; Falade *et al*., 2016; Sogbesan *et al*., 2017; Iyiola *et al.,* 2018; Nneji *et al*., 2020; Mojekwu *et al.,* 2020; Popoola *et al.,* 2022). However, information on the utilization of DNA barcodes to identify and distinguish tilapia species is dearth. Most of the samples from NW and SS (Nwani et al., 2011; Falade et al., 2016; Sogbesan et al., 2017; Mojekwu et al., 2020; Popoola et al., 2022). The barcode CO1 sequence has been shown to be highly variable and specific due to sequence divergence and conservation between and within species. This makes DNA barcoding an effective technology used in verifying several animal groups (Ward *et al.,* 2005; Hajibabaei *et al.,* 2007).

Nevertheless, mtDNA is maternally inherited and cannot account for events such as hybridization and incomplete lineage sorting prevalent among tilapia species. Hence, a significant limitation in utilizing mitochondrial markers in assessments of that phenomenon. However, some authors have used both mtDNA and nuclear markers in addressing introgressive hybridization (Anane-Taabeah *et al*., 2019; Ford *et al*., 2019). Assessment of tilapia diversity in Nigeria will require detailed sampling from various geographical river systems with proper morphological and genomic approaches to avoid taxonomic inaccuracies.

The present study aimed to assess relationships between tilapias from Nigeria stored in GenBank(Gene database). Confirm if there are taxonomic discrepancies between species based on the COI sequences. The author analyzed DNA barcodes of wild individuals found on the Barcode of Life Data system (BOLD) database(https://www.boldsystems.org/) and NCBI using a systematic method.

MATERIAL AND METHODS

Mining COI 5' (barcoding fragment) from BOLD and NCBI

BOLD system version 4 (www.boldsystems.org) and NCBI (https://www.ncbi.nlm.nih.gov) were used for the search on the 15th of July 2023. The search term used was "COI tilapia in Nigeria" (BOLD database → data portal → search query in public data →Input "tilapia COI in Nigeria" → search →download sequences as FASTA while in NCBI→ nucleotide → input "tilapia COI in Nigeria"→ click search → send to file → download sequences as FASTA). We discovered that *O. aureus* spp were not present using the above search terms. Hence to capture any tilapia like *O. aureus* not shown in previous search result, further search using the term ("Oreochromis COI in Nigeria") was done. A Complete mitochondrion reference genome sequences of *O. nil x O. aureus* Hybrid NC_025669.1, *Coptodon zillii* NC_026110.1, and *Oreochromis niloticus* NC_013663.1 were added for easy taxonomic placement. Furthermore, three species of non haplotilapiines COI sequences from different genera; *Heterochromis multidens* MK074351.1, *Tylochromis lateralis* MK074681.1 and *Pelmatochromis nigrofasciatus*, KT193197.1 were included as distant outgroups based on Dunz and Schliewen 2013. The combined sequences were trimmed in MEGA X (Kumar *et al.,* 2018) and ready for phylogenetic analysis.

Phylogenetic Analyses and BLASTN

Sequences retrieved from databases were edited, assembled and aligned using MEGA X (Kumar *et al.,* 2018). To compare and ascertain the best standard nucleotide substitution models, feature in MEGA X was applied for the model test, which ranked K2+G as the top models. Phylogenetic analysis derived from a maximum likelihood phylogeny was computed based on the best K2P+G substitution model (Tamura *et al.,* 2004), branch support of 500 bootstrap replicates and pair-wise deletion option to remove ambiguous positions for each sequence pair. BLAST search were further used to identify some unidentified Tilapia species based on the sequence similarity and coverage.

RESULTS

BOLD and NCBI search of tilapia COI indicated that all the 102 sequences downloaded in NCBI were present in Bold except one tilapia spp MT621195 (Table 1). The sequences were combined after filtering out duplicates to obtain 103 DNA barcodes. The search results for other tilapia spp using the term "Oreochromis COI in Nigeria" gave a total of 39 *Oreochromis spp*, which includes

30-number *O. niloticus* previously captured, 6-number *O. aureus* and 3-number *Oreochromis* unidentified. This showed that 9 sequences (6-number *O. aureus* and 3-number *Oreochromis* unidentified) were added to 103 sequences to give 112 (103+9). The three reference genomes from *Onil x Oureus* Hybrid, *Coptodon zillii*, and *Oreochromis niloticus* were also added while *Heterochromis multidens*, *Tylochromis lateralis* and *Pelmatochromis nigrofasciatus*, were included as outgroups. This brings it to a total of 118 (102+1+ 6+3+3 genomes+ 3 outgroups) sequences of COI from the database (Table 1). The sequence alignment was inspected and confirmed to be of good quality with no gaps or frameshift mutations. The final data set was a matrix of 118 COI sequences of wild tilapias trimmed to a length of 669bp, ready for phylogenetic analysis (Supplementary table: https://www.researchgate.net/publication/376189282).

Table 1: Number of Tilapia COI barcodes sequences in Nigeria retrieved from databases

S/N	Species	Accession numbers	Region	Number BOLD	Number NCBI	Others searches	Reference genomes	**Total**	BLASTn
1	*Coptodon zillii*	HM882904/ ON072283/, MG824685,4,2 /KY784688)	SE(Otuocha), NC(Jos /Kwara 3) NE (Yola)		36		1		
2	*Coptodon dageti*	HM882891, HM882900/ JF510523	SE(Afikpo 2/ Abakaliki		3				
3	*Coptodon guineensis*	HM882893,5, HM882908,07/ HM882916, HM882923,22, HM882911)	SE(Abakaliki 4/ Afikpo 4)		8				
4	*Oreochromis niloticus*	ON072283/ HM882892/ Mk497146-8/ KY784674/ MK130701-4/ NC 013663.1	NC (Jos)/ SE (Afikpo /osha), NE (Yola), NC (Makurdi 4)/ (Genome)		30		1		
5	*Pelmatolapia mariae*	HM882912, HM882905, HM882901/02/03	SE (Otuocha Anambra state)		5				
6	*Sarotherodon galilaeus*	KY784677, KY784681 / HM882890.	NE(Yola), SE(Abakaliki)		19				
7	*Unidentified Tilapia sp*	HM882892 /	SE(Afikpo)	1					*C. dageti*
		MT621195	SW (Ondo)		1				*C. camerunensis*
8	*Oreochromis aureus*	MG824627/8/9. MK130701/3/4	NC (Kwara 3), (Markurdi 3)			6			
9	*Unidentified Oreochromis*	MG824630/ MG824631/ MG824632	NC (Kwara),			3			*O. aureus*
10	*Onil x Oureus* Hybrid	NC025669.1 OnilXQaur	Hybrid Genome				1		
11	*H. multidens* *T. lateralis* *P.nigrofasciatus*	MK074351.1, MK074681.1, KT193197.1	DR Congo					3	
	Total			1	102	9	3	**118**	

Phylogenetic analysis showed two groups (Group 1 & 2) of Nile tilapia *O. niloticus* (Fig.1). Group 1 with 98% support value comprises sequences of *O. niloticus* and *O. aureus* from South East, North East and North Central, the three unidentified Oreochromis (MG824630 – 32) and the complete genome hybrid of *O. niloticus x O. aureus* species. Group 2 comprises of complete *O. niloticus* genome (NC 013663.1) and two *O. niloticus* species (MKY130700.1 & 2) from North Central.

Some Blue tilapia *O. aureus* from North Central were associted with *S. galilaeus* from South East and North East at 97% support value (Fig. 1). However, Group 1, *O. niloticus* and *S. galilaeus* are monophyletic at 100% support value and sister to group 2 at the same support value.

One unidentified Tilapia spp from South East (HM882892) were placed as sister to *C. dageti* while the other unidentified Tilapia spp. MT621195, collected from ondo in South West were identified as *C. camerunensis* (Fig. 1; Table 1) sharing a common clade with *C. guineensis* and *C. Zilli.*

All outgroups are from DR Congo as we could not find any COI sequences of those species from Nigeria on the database. Some other tilapia species found in Nigeria includes; *Chromidotilapia guntheri*, *Hemichromis camerounensis*, *Hemichromis fasciatus*, *Pelvicachromis taeniatus*, *Rubricatochromis bimaculatus*, *Rubricatochromis cristatus*, *Rubricatochromis cf. Guttatus*, *Thysochromis ansorgii*, *Tylochromis sudanensis* and many others.

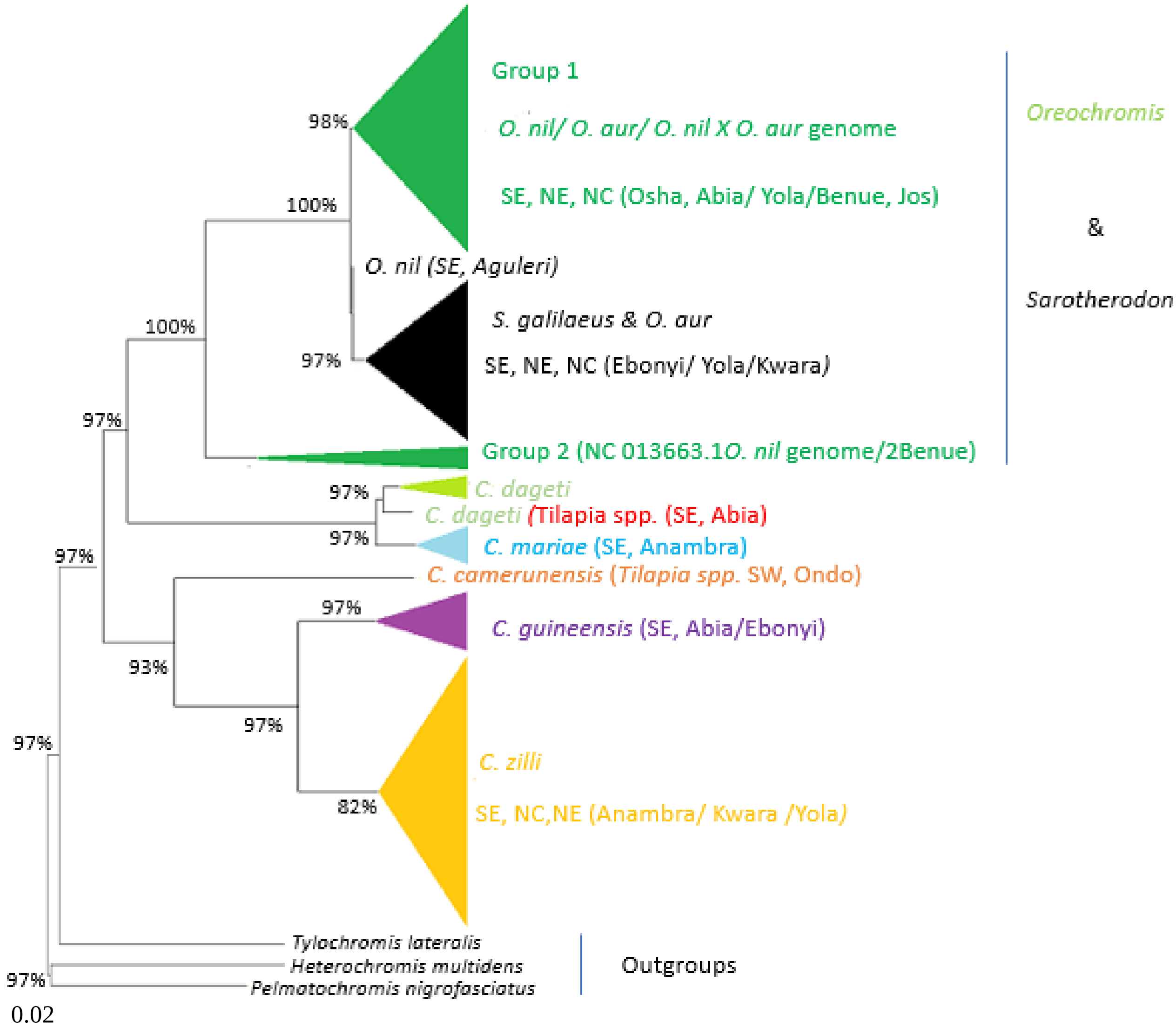

Fig 1: Maximum Likelihood tree of COI tilapia species barcodes in BOLD & NCBI from Nigeria

DISCUSSION

The presence of two groups of *O. niloticus* (Fig. 1) can be attributed to evolutionary complex history resulting from successive dispersal, divergence and secondary contact, reflecting history of river connections that resulted in the extensive native range of *O. niloticus* (Agnese *et al.*,1997; Bezault *et al.*, 2011; Decru *et al.*, 2016; Syaifudin *et al.*, 2019; Mojekwu *et al.*, 2020). Group 1 comprises sequence of *O. niloticus* and *O. aureus* from South

East (Niger River), North East (Yola) and North Central (N`gell/Gyel river Jos). The three unidentified Oreochromis (MG824630 – 32) from the second search term were placed in this group as *O. aureus*. Group 2 comprises of complete *O. niloticus* genome (NC 013663.1) and two *O. niloticus* species (MKY130700.1 &2) from Benue state (North Central), hence pure stocks of *O. niloticus* could exist in this region based on their association with the genome. Further assessment using nuclear markers will be required to validate these observations. Some authors have also reported several lineages of *O. niloticus* using mtDNA, attributing it to geographic barriers due to its large distribution, and introgression between aquaculture escapees and wild individuals (Bezault *et al*., 2007, 2011; Ford *et al.,* 2019; Mojekwu *et al.,* 2020).

Previous studies based on nuclear markers suggested that the clustering of *Sarotherodon galilaeus* within *Oreochromis* could be due to past hybridization events (Dunz and Schliewen 2013; Ford *et al.*, 2019). This is not surprising as both genera are common aquaculture species in Nigeria, known to hybridize even in captivity (Ayinla 2007; Otubusin 1988).

Phylogenetic and BLASTn search showed that Unidentified Tilapia spp (MT621195) and HM882892 collected from ondo in SW and Afikpo in SE were identified as *C. camerunensis* and *C. dageti* respectively (Table 1). Tilapia spp MT621195 shared a common clade with *C. guineensis* and *C. zilli*, its BLASTN search showed a 99.2% match (100% coverage) to *C. camerunensis* strain KJ938224.1 (BOLD ID: AEV0357) deposited by Kide *et al.*, 2016. This species is endemic to the Meme, Mungo, and Wouri Rivers of Cameroon (Lamboj 2004; Stiassny et al 2008), and needs to be conserved as its status on the IUCN Redlist is vulnerable (Moelants 2010). *C. guineensis* and *C. zilli* linked to this species are from river systems of NC (Jos, Kwara), SE (Afikpo, Abia Anambra, Enugu, Ebonyi, Abakaliki), and NE (Yola) that border Northern Cameroon. The presence of this (*Coptodon camerunensis*) species that is native to Cameroon could be a result of flooding that harmonizes local river systems within and between the two countries. Flooding is linked to heavy rainfall due to the impact of climate changes, worsened by the releases from the Ladgdo dam in Northern Cameroon causing overflowing of the Niger and Benue rivers with an impact on their tributaries. The BLASTN search of the second unidentified Tilapia sp with accession number HM882892 (Bold ID: BOLD: AAL6362) from Afikpo in Abia state of SE region showed it is a *C. dageti* with 98.92% closeness (100% coverage).

Hence, DNA barcode data is an important molecular resource for improving the knowledge of genetic variation within tilapia species. However, introgressive hybridization of tilapias in Nigeria can only be addressed properly using genomic assessment. Otherwise, how can you prove the purity of the tilapia species you are working with? We, therefore, recommend a multigene approach based on exome gene capture in addressing this problem.

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REFERENCES

Agnese, J. F., Adepo-Gourene, B., Abban, E. K. and Fermon, Y. (1997). Genetic differentiation among natural populations of the Nile tilapia, *Oreochromis niloticus* (Teleostei, Cichlidae). *Heredity*. 79: 88–96.

Adesulu, E.A. (1997). Current status of tilapia in Nigerian aquaculture. In: K. Fitzsimmons, ed. Proceedings of the Fourth International Symposium on Tilapia in Aquaculture, Orlando, USA pp.577-583..

Adesulu, E.A, and Sydenham, D. H. J. (2007). The freshwater fishes and fisheries of Nigeria. Macmillan Nigeria Publishers Ltd., Ibadan. 397pp

Anane-Taabeah, G., Frimpong, E. A. and Hallerman, E. (2019). Aquaculture mediated invasion of the genetically improved farmed tilapia (GIFT) into the lower volta basin of Ghana. *Diversity*. 11: 188.

Askew, A. J. (1999). Water in the International Decade for Natural Disaster Reduction. In Leavesley et al. (Eds.), Destructive Water: Water-caused Natural Disaster, their Abatement and Control. *IAHS* Publication No. 239.

https://www.researchgate.net/publication/265683760.

Ayinla, O.A. (2007). Analysis of feeds and fertilizers for sustainable aquaculture development in Nigeria. pp.453-470. In: Study and analysis of feeds and fertilizers for sustainable aquaculture development (Hasan, M.R., Hecht, T., De Silva, S.S. and Tacon, A.G.J., eds). FAO Fisheries Technical Paper No. 497. FAO, Rome. 510 pp.

Bbole, I., Katongo, C., Deines, A. M., Shumba, O. and Lodge, D. M. (2014). Evidence of hybridization between non-indigenous Oreochromis species in the lower Kafue River and its potential impacts on fishery. *Journal of Ecology and Natural Environment*. 6(6):215-225.

Bezault, E., Clota, F., Derivaz, M., Chevassus, B., and Baroiller, J.-F. (2007). Sex determination and temperature-induced sex differentiation in three natural populations of Nile tilapia (*Oreochromis niloticus*) adapted to extreme temperature conditions. *Aquaculture*. 272: S3–S16.

Bezault, E., Balaresque, P., Toguyeni, A., Fermon, Y., Araki, H., Baroiller, J. F. and Rognon, X. (2011). Spatial and temporal variation in population genetic structure of wild Nile tilapia (*Oreochromis niloticus*) across Africa. *BMC Genetics*.12: 102.

Canonico, G. C., Arthington, A., McCrary, J. K., and Thieme, M. L.(2005). The effects of introduced tilapias on native biodiversity. *Aquatic Conservation*.15(5):463-483. doi:10.1002/aqc.699.

Chukwu, M.N (2014). Impact of Flooding on Fishermen's families in Pedro Community, Iwaya-Lagos, Nigeria. *Journal of Applied Science Environment Management.* 18(4): 647- 651. http://dx.doi.org/10.4314/jasem.v18i4.13

Deines, A. M., Bbole, I., Katongo, C., Feder, J. L. and Lodge, D. M. (2014). Hybridisation between native Oreochromis species and introduced Nile tilapia *O. niloticus* in the Kafue River, Zambia. *African Journal of Aquatic Science*. 1–12 http://dx. doi.org/ 10.2989/ 16085914. 2013. 864965.

Dunz, A. R. and Schliewen, U.K (2013). Molecular phylogeny and revised classification of the haplotilapiine cichlid fishes formerly referred to as "Tilapia". *Molecular Phylogenetic Evoutionl*. 68(1):64-80. doi:10.1016/j.ympev.

Decru, E., Moelants, T., De Gelas, K., Vreven, E., Verheyen, E. and Snoeks, J. (2016). Taxonomic challenges in freshwater fishes: a mismatch between morphology and DNA barcoding in fish of the north-eastern part of the Congo basin. *Molecular Ecology Resources. 16*: 342–352.

El-Sayed, A-F. (2006). Tilapia Culture CABI Publications, Wallingford, UK. 275pp.

Fagbenro, O.A, Jegede, T. and Fasasi. O. S. (2010). Tilapia aquaculture in Nigeria. *Applied Tropical Agriculture.* 15: 49-55.

Firmat, C., Alibert, P., Losseau, M., Baroiller, J. F. and Schliewen, U. K. (2013). Successive invasion-mediated interspecific hybridizations and population structure in the endangered cichlid *Oreochromis mossambicus. PLOS ONE. 8(10):*10.1371.

Ford, A. G. P., Dasmahapatra, K. K., Rüber, L., Gharbi, K. and Day, J. J. (2015). High levels of interspecific gene flow in an endemic cichlid fish adaptive radiation from an extreme lake environment. *Molecular Ecology*. 24:3421–3440.

Ford, A. G. P., Bullen, T. R., Pang, L., Genner, M. J., Bills, R., Flouri, T., Ngatunga, B. P., Rüber, L., Schliewen, U. K., Seehausen, O., Shechonge, A., Stiassny, M. L. J., Turner, G. F. and Day, J. (2019). Molecular phylogeny of Oreochromis (Cichlidae: Oreochromini) reveals mito-nuclear discordance and multiple colonisation of adverse aquatic environments. *Molecular Phylogenetics and Evolution*. *136*: 215-226 ISSN 1055-7903. https://doi.org/10.1016/j. ympev.2019.04.008.

Froese R and Pauly D. (2018). FishBase World wide web electronic publication. version. Accessed June, 2018. https://www.fishbase.de/Introductions/IntroductionsList.php?ID=2&GenusName=Oreochromis&SpeciesName=niloticus&fc=349&StockCode=1

Falade, M.O., Opene, A, J. and Benson, O. (2016). DNA barcoding of *Clarias gariepinus, Coptodon zillii* and *Sarotherodon melanotheron* from Southwestern Nigeria. *Research.* 5:1268 DOI 10.12688/f1000research.7895.1.

Hajibabaei, M., Singer, G. A. C., Hebert, P. D. N. and Hickey, D.A. (2007). DNA barcoding: How it complements taxonomy, molecular phylogenetics and population genetics. *Trends in Genet*ics. 23: 167-172.

Horsfall, G. B., Obafemi, A. A. and Ogoro, M. (2023). Spatial analysis of the probability and severity of flood events in Rivers and Bayelsa States, Niger Delta Region, Nigeria. *International Journal of Science and Research Archiv*e. 9(02): 452–460. https://doi.org/10.30574/ijsra.2023.9.2.0561

Idodo-Umeh, G. (2003). Freshwater fishes of Nigeria (taxonomy, ecological notes, diet and utilization). 1st edition. Ldodo-Umeh Publishers Ltd, Benin City, Nigeria. 238pp.

Ishaya, B., Jinga, J., John Ayuba, G., Nehemiah, J.and Rafiyatu, H. (2023). Flood risk assessment of the river Benue catchment in Adamawa State Nigeria.*World Journal of Advanced Research and Reviews.* 19(01): 347–368. https://doi.org/10.30574/wjarr.2023.19.1.1298,

Iyiola, O. A., Nneji, L. M., Mustapha, M. K., Nzeh, C. G., Oladipo, S. O., Nneji, I. C., Okeyoyin, A. O., Nwani, C. D., Ugwumba, O. A., Ugwumba, A. A. A., Faturoti, E. O., Wang, Y-Y, Chen, J., Wang, W-Z. and Adeola, A. C. (2018). DNA barcoding of economically important freshwater fish species from north-central Nigeria uncovers cryptic diversity. *Ecology and Evolution*. 8(14): 6932–6951. DOI 10.1002/ece3.4210.

Kadarusman, Hubert, N., Hadiaty, R. K., Paradis, E., and Pouyaud, L.. (2012). Cryptic diversity in Indo-Australian rainbowfishes revealed by DNA barcoding: implications for conservation in a biodiversity hotspot candidate. *PLoS One.* 7: e40627.

Kumar, S., Stecher, G., Li, M., Knyaz, C. and Tamura, K. (2018). MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. *Molecular Biology and Evolution*. 35:1547-1549.

Kakioka, R., Muto, N., Takeshima, H., Gaje, A. C., Cruz, R. S., Alama, U. B., and Ishikawa, S. (2018). Cryptic genetic divergence in Scolopsis taenioptera (Perciformes: Nemipteridae) in the western Pacific Ocean. *Ichthyological Research*. 65: 92–100. https://doi.org/10.1007/s10228-017-0596-1

Kide, N. G., Dunz, A, Agnèse, J. F., Dilyte, J., Pariselle, A., Carneiro, C., Correia, E., Brito, J. C., Yarba, L. O., Kone, Y. and Durand, J. D. (2016). Cichlids of the Banc d'Arguin National Park, Mauritania: insight into the diversity of the genus Coptodon. *Journal of Fish Biology*.88(4):1369-93. doi: 10.1111/jfb.12899.

Lamboj, A. (2004). The Cichlid Fishes of Western Africa. Birgit Schmettkamp Verlag, Bornheim, Germany. 255 p. DOI : 3-928819-33-X

McAndrew, B. J. (2000). Evolution, phylogenetic relationships and biogeography. In: Beveridge, M.C.M., McAndrew, B.J. (eds) Tilapias: Biology and Exploitation. Fish and Fisheries Series, vol 25. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-4008-9_1

Mwanja, W. W., Fuerst, P. A. and Kaufman, L. (2012). Reduction of the “ngege”, Oreochromis esculentus (Teleostei: Cichlidae) populations, and resultant population genetic status in the Lake Victoria region. Uganda *Journal of Agricultural Science*. 13: 65–82.

Moelants, T. (2010). Coptodon camerunensis. The IUCN Red List of Threatened Species 2010: e.T181578A7683498. https://dx.doi.org/10.2305/IUCN.UK.20103.RLTS.T181578A7683498.en. Accessed on 23 June 2023

Mojekwu, T. O., Cunningham, M. J,. Bills, R. I., Pretorius, P. C. and Hoareau, T. B. (2020). Utility of DNA barcoding in native Oreochromis species. *Journal of Fish Biology.* 9(4). https://doi.org/10.1111/jfb.14594

Nneji, L. M., Adeola, A. C., Mustapha, M. K., Oladipo, S. O., Djagoun, C. A. M. S., Nneji, I. C., Adedeji, B. E., Olatunde, O., Ayoola, A. O., Okeyoyin, A.O, Ikhimiukor, O. O., Useni, G. F., Iyiola, O. A, Faturoti, E. O., Matouke, M. M., Ndifor, W. K., Wang, Y-Y., Chen, J., Wang, W-Z., Kachi, J. B., Ugwumba, O. A., Ugwumba, A. A. A. and Nwani, C. D. (2020). DNA barcoding silver butter catfish (*Schilbe intermedius*) reveals patterns of mitochondrial genetic diversity across african river systems. *Scientific Reports.* 10(1):1–9 DOI 10.1038/s41598-020-63837-4.

Nwakanma, C., Ude, G. and Unachukwu, M. N. (2015). The use of DNA barcoding in identification of genetic diversity of fish in Ugwu-Omu Nike River in Enugu. *Nigerian Journal of Biotechnology*. 29(1): 27–33 DOI 10.4314/njb.v29i1.4.

Nwani, C. D., Becker, S., Braid, H. E., Ude, E. F., Okogwu, O. I. and Hanner, R. (2011). DNA barcoding discriminates freshwater fishes from southeastern Nigeria and provides river system-level phylogeographic resolution within some species. *Mitochondrial DNA* 22(sup1):43–51 DOI 10.3109/19401736.2010.536537.

Odufuwa, B.O., Adedeji, O.H., Oladesu, J.O. and Bongwa, A. (2012). Floods of fury in Nigerian cities. *Journal of Sustainable Development.* 5(7): 69–79. DOI:10.5539/jsd.v5n7p69

Otubusin, S. O. (1988). Hybridization trials using *Oreochromis niloticus* and *Sarotherodon galilaeus* in floating bamboo net-hapas in Kainji Lake Basin, Nigeria. *Aquaculture*. 74(3–4):233–237 DOI 10.1016/0044-8486(88)90367-5.

Popoola, M. O., Schedel, F. D. B., Hebert, P. D. and Schliewen, U. K. (2022). First DNA barcode library for the ichthyofauna of the Jos Plateau (Nigeria) with comments on potential undescribed fish species. *PeerJ.* 10:e13049 DOI 10.7717/peerj.13049

Philippart, J. C. and Ruwet, J. C. (1982). Ecology and distribution of tilapias. In: Pullin RSV, Lowe McConnell, RH, eds. The Biology and Culture of Tilapias.ICLARM Conference Proceedings No. 7:15-59.

Syaifudin, M., Bekaert, M., Taggart, J. B., Bartie, K. L., Wehner, S., Palaiokostas, C., Khan, M. G. Q., Selly, S. C., Hulata, G., D'Cotta, H., Baroiller, J., McAndrew, B. and Penman, D. J. (2019). Species-specific marker discovery in tilapia. *Scientific Report*. 9: 13001.

Shechonge, A., Ngatunga, B. P., Tamatamah, R., Bradbeer, S. J., Sweke, E., Smith, A., Turner, G. F. and Genner, M. J. (2019). Population genetic evidence for a unique resource of Nile tilapia in Lake Tanganyika, East Africa. *Environmental Biology of Fishes.* 102(8):1107-1117. doi:10. 1007/s10641-019-00895-2.

Sogbesan, O. A., Sanda, M. K., Jaafar, N. J. and Adedeji, H. A. (2017). DNA barcoding of tilapia species (Pisces: Cichlidae) from North-Eastern Nigeria. *Journal of Biotechnology & Biomaterials.* 7:4. DOI 10.4172/2155-952X.1000277.

Stiassny, M., L. J. A., Lamboj, D., De Weirdt, and Teugels, G. G. (2008). Cichlidae. p. 269-403. In M.L.J. Stiassny, G.G Teugels and C.D. Hopkins (eds.) The fresh and brackish water fishes of Lower Guinea, West-Central Africa Volume 2. Coll. faune et flore tropicales 42. Institut de recherche de développement, Paris, France, Muséum national d'histoire naturelle, Paris, France and Musée royal de l'Afrique Central, Tervuren, Belgium, 603p.

Tamura, K., Nei, M. and Kumar, S. (2004). Prospects for inferring very large phylogenies by using the neighbour-joining method. Proceedings of the National Academy of Sciences (USA). 101:11030-11035.

Umar, N. and Gray, A (2022). Flooding in Nigeria: a review of its occurrence and impacts and approaches to modelling flood data. *International Journal of Environmental Studies.* 31;1–22. DOI: 10.1080/00207233.2022.2081471

Ward, R. D., Zemlak, T. S., Innes, B. H., Last, P. R. and Hebert, P. D. N. (2005). DNA barcoding Australia's fish species. Philosophical Transactions of the Royal Society of London Series B-*Biological Sciences.* 360:1847-1857.

Wu, L. and Yang, J. (2012). Identifications of captive and wild tilapia species existing in Hawaii by mitochondrial DNA control region sequence. *PLoS One*.7: e51731. https://doi.org/10.1371/journal. pone.0051731.

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BACTERIOLOGICAL DIVERSITY OF THE ORGANS OF *Clarias gariepinus*, *Chrysichthys nigrodigitatus*, AND *Oreochromis niloticus* FROM KATSINA-ALA AND IBI RIVERS

***UMMA S. B., S. UJAH, B. GANI AND R. Z. AGU**
Department of Fisheries and Aquaculture, Federal University Wukari, Taraba State, Nigeria.
*Corresponding Author: umma@fuwukari.edu.ng, +2348076334395

ABSTRACT
Knowledge of the bacteriological load of fish is important for public health as fish are easily susceptible to bacterial attack due to their nature. Therefore, this study aimed at assessing the relative microbial loads of gills, intestine, and skin of Oreochromis niloticus, Chrysichthys nigrodigitatus, and Clarias gariepinus from Katsina-Ala and Ibi Rivers. Targeted fishes (n= 120) were randomly collected from fishermen at the landing sites, grouped and aseptically transported alive using oxygenated nylon bags to Microbiology Laboratory for bacteriological assay using standard procedures. Aseptically, spread and pour plate methods were carried out for gills, intestinal samples and skin respectively. Bacterial loads from the organs of the fishes in both locations were significantly different (P < 0.05). Specifically, the gills of Oreochromis niloticus had significantly more bacterial load than Chrysichthys nigrodigitatus and Clarias gariepinus. Similarly, the intestine and skin of Clarias gariepinus had more bacterial loads. In comparison, total bacterial viable counts (CFU/g) of the gills for Chrysichthys nigrodigitatus and Oreochromis niloticus were significantly higher in Ibi River, same for the intestine and skin of Oreochromis niloticus. Generally, bacteriological loads of the targeted fishes were higher in Ibi River; however, in some instance they were below the acceptable limits for food safety.

Keywords: Acceptable limits; Bacteriological loads; Fish; public health; Ibi River; Katsina-Ala River

INTRODUCTION

Fish is one of the most sought-after sources of animal protein food, constituting an integral part of the diet of man worldwide (Eze *et al*., 2011; Olugbojo and Ayoola, 2015; Svanberg, 2021). They are consumed for their high biological values (HBV) in terms of high protein retention in the body, presence of essential amino acids, and relatively low cholesterol (Mohanty *et al*., 2014; Tacon *et al*., 2020). According to Emikpe *et al.*(2011), fish contribute about 60% of global animal protein demand, and 60% of the developing countries derive over 30% of their animal protein from fish. Fish are generally regarded as safe, nutritious, and beneficial for man's consumption and health, however, both wild and aquaculture species are often associated with some food safety issues (WHO, 2007). The increasing human population, activities, and interest in the aquatic ecosystem have led to a huge upset in the survival and propagation of fish due to the high emergence of disease-causing bacteria and their antibiotic effect on man (Meijide *et al.*, 2018; Zhu *et al.*, 2018; Schmeller *et al.*, 2018). Microbes causing disorder in aquatic ecosystems, infections and mortality in fishes are directly linked to food security concerns due to inadequate animal protein sources and post-harvest losses (Ziarati *et al.*, 2022).

The presence of bacteria in fish could play diverse roles, some of which might be beneficial to the fish, but its adverse effect is both dangerous to the fish and the man that consumes it (Wasng, *et al*., 2019; Vanamala *et al*., 2022). Bacteria are transmitted by fish that have made contact with other diseased fish. Bacteria fish disease and infections are very common and are one of the most difficult health challenges. Most bacterial diseases display common symptoms, particularly in fish**.** Bacterial infection can occur in the muscles, internal organs, skin, fins, and exoskeleton (Vanamala *et al*., 2022).

The African catfish (*Clarias gariepinus*) has been reported to be a very important freshwater fish for aquaculture industries (Federal Department of Fisheries, 2007) due to some of its advantageous qualities like tolerance to wide fluctuations in environmental conditions, fast growth, high fecundity, artificial breeding success, and palatability (Eyo *et al*., 2014; Fagbuaro *et al*., 2015). Its consumption is on the increase in both rural and urban areas due to its high nutritive value (Federal Department of Fisheries, 2007; Emikpe *et al*., 2011). Catfishes generally are important fish species in the inland water bodies of Africa because of their high commercial value.

The Nile tilapia (*Oreochromis niloticus)* is one of the most commonly farmed and commercialized fish species around the world because of its high rate of growth and consumer preferences (Mortuza and Al-Misned, 2013), It can grow and reproduce in a wide range of environmental conditions and tolerate stress induced by handling (Tsadik and Bart, 2007), and is also considered as a model to reduce the gap in aquaculture nutrition (Kapinga *et al.,* 2014). However, Nile tilapia is commonly associated with many bacterial loads, and studies have shown that different organs of this species carry a wide variety of bacteria (Mandal *et al.,* 2009; Eissa *et al.,* 2010).

The Silver catfish *(Chrysichthys nigrodigitatus)* is a highly valued food fish occurring in several African waters, It is among the dominant fish species of commercial importance, occurring all year round with peak abundance in the rainy season, (Holzloehner *et al*., 2007; Ama-Abasi *et al*., 2017), However, Uyoh *et al.,* (2020), reported that *Chrysichthys nigrodigitatus* of some water body has very low genetic diversity and that such low genetic diversity can lead to population eradication in the face of environmental variability and microbial infections.

Fish generally are vulnerable and quick to spoilage primarily by the action of enzymes and bacteria on the fish post-harvest due to its biological nature of high moisture, fat content, and high protein content, and also due to weak muscle tissue and low levels of carbohydrates (Murthy and Jeyakumari, 2019). Therefore, man must be mindful of his anthropogenic activities relating to the aquatic ecosystem. In addition, practice safe use of aquatic resources, healthy fishing activities, and hygienic handling of fish post-harvest to reduce fish susceptibility to microbial attack and spoilage. Microbiological quality study of fish has great importance to public health as it is directly related to spoilage of fish and food poisoning, so it is important to monitor the quality of harvested freshwater fish to ensure that the level of microbes is within the acceptable limits, and also reduce the health risk to end users.

Bacterial infection of fish is generally considered one of the major constraints of output for both wild and aquaculture fish species. This makes it necessary to determine the microorganisms of various fishes of economic importance in the wild and also their safety limits. Therefore, this study aimed at assaying the bacteriological loads of the gills, intestine, and skin of catfish (*Clarias gariepinus*), silver catfish (*Chrysichthys nigrodigitatus*), and tilapia (*Oreochromis niloticus)* from two major fish landing sites in lower River Benus, Ibi Local Government area of Taraba State and major tributary of River Benue in Katsina-Ala Local Government area of Benue State.

MATERIALS AND METHODS

Study Area

Katsina-Ala and Ibi Local Government Areas are in Benue State north-central and Taraba State north-east of Nigeria, respectively. River Katsina-Ala is a major tributary of River Benue, and the lower River Benue at Ibi has a confluence with River Katsina-Ala in Agasha town of Guma Local Government Area, Benue State (Figure 1).

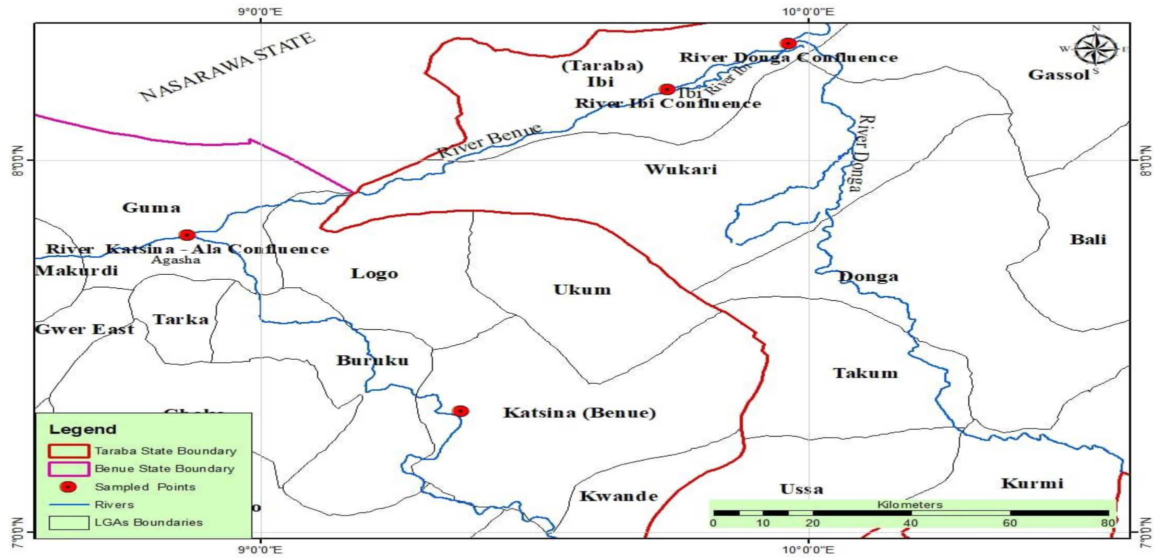

Figure 1: Map showing the sample points in both Katsina-Ala River and lower River Benue at Ibi, and their confluence points

Collection of fish samples from the landing sites

A total of one hundred and twenty (n=120) random samples of fishes (*Chrysichthys nigrodigitatus*, *Oreochromis niloticus*, and *Clarias gariepinus*) were immediately collected from the fishermen on arrival at the River Ibi and Katsina-Ala landing sites, and were further separated into three groups of twenty (20) fish species each and transferred aseptically in separate oxygenated nylons to the Microbiology laboratory of the Federal University Wukari for microbial analysis.

Preparation of culture media

The culture media used were Plate Count Agar (PCA) and Nutrient Agar (NA). Each of them was prepared according to the manufacturer's instructions (Oxoid Ltd) and autoclaved at a temperature of 121^0c and a pressure of 15psi for a period of 15munites, then allowed to cool to 45^OC before use (Oscroft and Correy, 1991).

Isolation of bacteria from the gills, intestine, and skin of sampled fishes

One gram (1g) of both gills and intestine was aseptically collected and pooled from each of the dissected fish samples made up of three groups of 20 fish species each in the separate landing sites. The collected samples were homogenized in 10 mL of normal saline and serially diluted using 10-fold serial dilutions. An aliquot from dilution 10^6 was used. The pour plate method was used for the primary isolation of bacteria from the serially diluted gill and intestinal samples by putting 1mL from the selected dilutions into Petri dishes with already cooled and solidified molten nutrient agar and swirling properly for inoculation. The spread plate method was used for the primary isolation of bacteria from the fish skin swabbing. The inoculated plates were incubated at 37^OC for 24 hours. Bacteria isolates were purified by repeated sub-culturing onto freshly prepared sterile nutrient agar using the streak plate method as described by Katz (2008).

Microscopic analysis

The bacteria isolates were morphologically examined for size, color, shape, and pigmentation. The isolates were morphologically identified based on cultural and microscopic characteristics as described by Váradi *et al*. (2017). Pure isolates were picked using a sterile inoculating needle and placed on a sterile grease-free microscope slide, the slide containing the bacteria culture was heat fixed under a hot flame using the Bunsen burner. The heat-fixed slide was stained using the gram staining reagent after which the stained slide was allowed to air dry. The slide was viewed under the microscope using an x100 objective lens (oil immersion lens). This was done to check and determine the colony characteristics and gram reaction of the bacteria isolates.

Biochemical test

Briefly, isolates were further identified by gram stain, motility, catalase, oxidase, coagulase, and IMViC reactions as follows:

Gram staining procedures

A smear of each isolate was made on a grease-free slide and heat-fixed properly. Crystal violet which is the primary stain was added to each slide and allowed to stay for 60 seconds after which it was washed off using clean running water. Grams iodine was added as mordent for 60 seconds and washed off. The slides were decolorized using 95% ethanol to remove excess stains and rinse with water. The slides were counterstained using a secondary stain called Safranin and rinsed with tap water. The slides were air-dried and observed under a microscope using X100 objective (oil immersion) for morphological characteristics as described by Cardoso *et al*. (1998).

Catalase

2mL of hydrogen peroxide solution was placed inside the test tube. Colonies of the culture were picked using a sterile glass rod after an 18 to 24-hour test and immersed in the hydrogen peroxide to observe the bubbling of gas (Sapkota, 2020).

Coagulase test

1mL of plasma was added to test tubes and a loopful of the bacteria isolates were inoculated. The test tubes were incubated at 37^0C for 1 hour in a water bath to observe for the presence of clouding and clotting.

Oxidase

The tetramethyl-p-phenylenediamine dihydrochloride substrate was used to soak filter paper. Sterile distilled water was used to moisten the paper and the colony was picked using a sterile platinum loop and observed for any color change to deep blue or purple between 10 to 30 seconds (Shield and Cathcart, 2010).

Indole test

An 18 to 24-hour culture inoculum was placed aseptically in a sterilized test tube with 4mL of prepared tryptophan broth. It was incubated at 37^OC for 24 to 28 hours, and 0.5mL of Kovac's reagent was introduced into the broth culture and observed for the presence of the ring (Kar *et al*., 2017).

Methyl red test

The isolated colonies were inoculated into glucose phosphate broth, which contains glucose and a phosphate buffer, and incubated at 37^0C for 24 hours. The pH of the medium was tested by the addition of 5 drops of methyl red reagent, to check for either red color indicating positive results or yellow color indicating negative results.

Voges-Proskauer test

The isolated colonies were inoculated into glucose phosphate broth and incubated at 37^0C for 24 hours. 0.6 ml of alpha-naphthol was added to the test broth and shaken. 0.2 ml of 40% KOH was added to the broth and shaken. The test tube was allowed to stand for 15 minutes, to check for the appearance of a red color indicating a positive result or not.

Citrate utilization test

Isolated bacterial colonies were picked

with a sterile inoculating loop and inoculated into slants of Simmon's citrate agar and incubated at 37^0C, to check if the organism can utilize citrate by changing the medium color from green to blue.

Data Analysis

Anderson-Darling Normality test was used to check the normality of the distribution and the homogeneity of variance obtained. Data on total bacterial viable counts on the gills, intestine, and skin of the fish species were analyzed statistically using ANOVA. The significant difference of the means of bacteria species was carried out using Tukey HSD. Then, a t-test was used to compare the mean difference of bacteria on the organs of the fish species in the two locations. All the statistical analysis was done with the aid of Minitab statistical software program version 19 (Minitab® LLC, Pennsylvania, USA).

RESULTS

Morphometric characteristics of the isolated bacteria of the gills, intestine and skin of *Clarias gariepinus*, *Chrysichthys nigrodigitatus*, and *Oreochromis niloticus*

The morphological characteristics of the isolated bacteria (Table 1) indicated their distinct characteristics ranging from small–to large colony sizes, with varying colors. Most of them were non-lactose fermenters, except for *Escherichia coli and Klebsiella Sp.* They all indicated negative gram staining reactions and rod-shaped appearance, except *Bacillus sp* which was gram-positive.

Bacteriological status of the gills, intestine and skin of *Clarias gariepinus*, *Chrysichthys nigrodigitatus* and *Oreochromis niloticus* in Katsina-Ala and Ibi Rivers.

The microbial loads of the gill, intestine and skin of the three (3) species of fish from Katsina-Ala as shown in Table 2 indicated that there was a significant difference ($P < 0.05$) in the total viable counts in the gill, intestine, and skin of *Clarias gariepinus*, *Chrysichthys nigrodigitatus*, and *Oreochromis niloticus* respectively. In specific, the intestine of *Clarias gariepinus* significantly harbored more of the bacterial species isolated, while the gills of *Oreochromis niloticus* harbored more of the bacterial species isolated except *Flavobacterus sp, Proteus sp, Salmonella sp,* and *Shigella sp* in *Clarias gariepinus.* The skin of *Clarias gariepinus* was noticed to have the highest levels of the identified bacterial species isolates. The pooled standard deviation was not wide among all the samples ranging from 0.2 – 0.3. Instances where the R-square values of the model were very high indicated a strong relationship between the bacterial isolates (dependent variable) and the various organs (independent variables) of the three (3) species investigated.

Similarly, it was observed that the same fish species (*Clarias gariepinus*, *Chrysichthys nigrodigitatus*, and *Oreochromis niloticus)* in Ibi River were having the same pattern of bacterial loads on the gills as in River Katsina-Ala, with *Oreochromis niloticus* having the highest bacterial loads in all the isolated species of bacteria (Table 3). The intestinal bacterial loads of the isolated bacteria in the Ibi River were higher in *Clarias gariepinus* but not significantly different ($P > 0.05$) between *Chrysichthys nigrodigitatus* and *Oreochromis niloticus*. The skin of *Clarias gariepinus* in the Ibi River like the Katsina-Ala River had a similar trend in bacterial loads among the three (3) fish species investigated except for *Proteus sp.* and *Shigella sp* in *Oreochromis niloticus*. The observed summary of the results in both Rivers shows that *Clarias gariepinus* significantly had more bacteria loads in the intestine and on the skin, while *Oreochromis niloticus* had more in the gills. The pooled standard deviation was not also wide among the samples with a range of 0.18 – 0.22. Instances where the R-square values of the model were very high indicated a strong relationship between the bacterial isolates (dependent variable) and the various organs (independent variables) of the three (3) species investigated.

Table 1: Morphological characteristics of the isolated bacteria of the gills, intestine, and skin of *Clarias gariepinus*, *Chrysichthys nigrodigitatus*, and *Oreochromis niloticus in* Rivers Katsina-Ala and Ibi

Bacteria	Morphological characteristics	Gram stain reaction
Pseudomonas aeruginosa	Moderate, moist, blue-green non-lactose fermenter colonies	Gram-negative rod-shaped
Bacillus sp	Small, moist white or pale-yellow non-lactose fermenter colonies	Gram-positive rod-shaped
Escherichia coli	Moderate, moist yellow lactose fermenter colonies	Gram-negative rod-shaped
Flavobacterus sp.	Large, moist yellowish-brown, non-lactose fermenter colonies	Gram-negative rod-shaped
Klebsiella sp.	Large, moist red lactose fermenter colonies	Gram-negative rod-shaped
Aeromonas sp.	Moderate, moist, dark-green non-lactose fermenter colonies	Gram-negative rod-shaped
Proteus sp.	Small, smooth, pale non-lactose fermenter colonies	Gram-negative rod-shaped
Salmonella sp.	Small, moist pale-yellow non-lactose fermenter colonies	Gram-negative rod-shaped
Shigella sp.	Small, moist, blue-green non-lactose fermenter colonies	Gram-negative rod-shaped

Table 2: Bacteria load (10^6 CFU/g) of the gills, intestine, and Skin of *Clarias gariepinus, Chrysichthys nigrodigitatus*, and *Oreochromis niloticus* in River Katsina-Ala

Means with different superscripts along the row are significantly different (P < 0.05). Cg-*Clarias garipienus*, Cn- *Chrysichthys nigrodigitatus*, On- *Oreochromis niloticus*

Parameters	Gils *Cg*	Gill *Cn*	Gill *On*	Pooled StDev	R^2	Intestine *Cg*	Intestine *Cn*	Intestine *On*	Pooled StDev.	R^2	Skin *Cg*	Skin *Cn*	Skin *On*	Pooled StDev.	R^2
Pseudomonas sp	7.0^{c}	7.8^{b}	9.6^{a}	0.2	97.8	13.6^{a}	11.4^{b}	11.8^{b}	0.2	97.1	9.6^{A}	6.2^{C}	7.2^{B}	0.2	98.7
Bacillus sp	9.5^{b}	11.6^{a}	11.6^{a}	0.2	97.5	18.3^{a}	17.2^{b}	14.3^{c}	0.2	99.2	12.9^{A}	9.2^{B}	8.4^{C}	0.2	99.3
Flavobacterus sp	5.2^{a}	5.4^{a}	4.3^{b}	0.2	89.9	10.1^{a}	8.1^{b}	5.3^{c}	0.2	99.3	7.1^{A}	4.3^{B}	2.8^{C}	0.5	95.6
Klebsiella sp	5.3^{c}	7.1^{b}	7.9^{a}	0.2	98.1	10.3^{a}	10.5^{a}	9.7^{b}	0.2	80.4	7.3^{A}	5.6^{B}	5.9^{B}	0.2	96.6
Aeromonas sp	1.0^{b}	0.6^{b}	1.8^{a}	0.3	81.5	2.0^{a}	0.9^{b}	1.8^{a}	0.2	87.7	1.4^{A}	0.4^{B}	1.0^{A}	0.2	85.0
Proteus sp	3.1^{a}	3.1^{a}	0.8^{b}	0.2	97.9	6.2^{a}	4.7^{b}	1.0^{c}	0.2	99.4	4.3^{A}	2.5^{B}	0.5^{C}	0.2	98.9
Salmonella	2.5^{ab}	2.8^{a}	2.3^{b}	0.2	62.8	5.0^{a}	4.1^{b}	2.8^{c}	0.2	96.9	3.5^{A}	4.9^{A}	1.6^{A}	2.6	28.3
Shigella sp	2.7^{a}	2.4^{a}	2.4^{a}	0.2	46.1	5.4^{a}	3.6^{b}	3.0^{c}	0.2	97.5	3.8^{A}	1.9^{B}	1.8^{B}	0.2	97.3
Escherichia coli	6.3^{c}	8.9^{b}	9.9^{c}	0.2	98.6	12.3^{b}	13.4^{a}	12.2^{b}	0.2	87.6	8.7^{A}	7.1^{B}	7.4^{B}	0.2	94.6

Table 3: Bacteria load ((10^6 CFU/g) of the gills, intestine, and Skin of *Clarias gariepinus, Chrysichthys nigrodigitatus* and *Oreochromis niloticus* in River Ibi

Parameters	Gills *Cg*	Gills *Cn*	Gills *On*	Pooled StDev	R^2	Intestine *Cg*	Intestine *Cn*	Intestine *On*	Pooled StDev.	R^2	Skin *Cg*	Skin *Cn*	Skin *On*	Pooled StDev.	R^2
Pseudomonas sp	6.2^{c}	8.3^{b}	9.8^{a}	0.2	98.8	13.5^{a}	13.4^{a}	13.4^{a}	0.2	7.7	9.2^{a}	6.2^{b}	3.8^{c}	0.2	99.7
Bacillus sp	9.2^{c}	10.6^{b}	13.6^{a}	0.2	99.2	20.2^{a}	19.2^{b}	19.23^{b}	0.18	90.4	13.7^{a}	9.2^{c}	10.2^{b}	0.2	99.9
Flavobacterus sp	4.3^{c}	6.1^{b}	7.4^{a}	0.2	98.4	11.2^{a}	10.0^{b}	10.1^{b}	0.2	91.0	6.5^{a}	4.3^{c}	5.3^{b}	0.2	96.7
Klebsiella sp	5.6^{b}	9.4^{a}	9.0^{a}	0.3	97.9	13.5^{a}	12.5^{b}	12.5^{b}	0.2	89.7	8.3^{a}	5.6^{b}	3.6^{c}	0.2	99.3
Aeromonas sp	0.4^{c}	4.6^{a}	0.4^{b}	0.2	99.8	2.9^{a}	1.9^{b}	2.9^{b}	0.22	88.2	0.7^{b}	0.4^{b}	2.4^{a}	0.2	96.6
Proteus sp	2.5^{c}	7.1^{a}	5.1^{b}	0.2	99.3	9.7^{a}	6.7^{b}	6.7^{b}	0.2	97.8	3.7^{b}	2.5^{c}	4.5^{a}	0.2	96.4
Salmonella	2.2^{c}	7.8^{a}	4.8^{b}	0.2	99.5	7.2^{a}	6.2^{b}	6.7^{ab}	0.2	86.2	3.3^{a}	2.2^{b}	2.2^{b}	0.2	91.3
Shigella sp	1.9^{c}	7.4^{a}	4.4^{b}	0.2	99.5	7.6^{a}	5.6^{b}	5.6^{b}	0.2	97.1	2.9^{b}	1.9^{c}	3.8^{a}	0.2	95.9
Escherichia coli	7.1^{c}	9.9^{b}	11.0	0.2	99.1	16.4^{a}	15.3^{b}	15.3^{b}	0.2	90.8	10.6	7.1^{b}	7.1^{b}	0.2	99.0

Means with different superscripts along the row are significantly different (P < 0.05). *Cg-Clarias garipienus, Cn- Chrysichthys nigrodigitatus, On- Oreochromis niloticus*

Comparison of the bacteria load of the gills, intestine, and skin of *Clarias gariepinus, Chrysichthys nigrodigitatus,* and *Oreochromis niloticus*

The comparison of the total bacteria loads between the fishes of River Katsina-Ala and Ibi (Table 4) indicated that there is no significant difference (P < 0.05) in the total viable counts of bacteria on the gills on *Clarias gariepinus* in both Rivers. However, there was a strong significant difference in both *Chrysichthys nigrodigitatus* and *Oreochromis niloticus* in River Katsina-Ala and Ibi respectively, with the highest loads in Ibi River. The intestinal bacteria loads in the three (3) fish species showed a strongly significant difference (P < 0.05) in both the Katsina-Ala River and Ibi River, with the highest loads in the Ibi River. The skin of the fish species in both Rivers showed no significant difference between *Clarias gariepinus* and *Chrysichthys nigrodigitatus*, except *Oreochromis niloticus*, where it was significantly higher in the Ibi River.

Table 4 Total bacterial viable counts (10^6 CFU/g) of the gills, intestine, and skin of *Clarias gariepinus, Chrysichthys nigrodigitatus*, and *Oreochromis niloticus* in the two locations

Organs	Species	Katsina-Ala	Ibi	T-Value	P-Value	DF	Pooled StDev.
Gills	Cg	4.73±1.80	4.36±1.77	2.20	0.093	4	1.7851
	Cn	5.51±1.80	7.90±1.31	-16.74	0.00	4	1.5767
	On	5.62±1.33	7.52±1.80	-13.27	0.00	4	1.5832
Intestine	Cg	9.25±1.89	11.37±1.85	-12.99	0.00	4	1.7876
	Cn	8.21±1.89	10.10±1.85	-11.15	0.00	4	1.8702
	On	6.88±1.80	10.27±1.75	-21.06	0.00	4	1.7753
Skin	Cg	6.51±1.75	6.55±1.80	-0.25	0.813	4	1.7753
	Cn	4.67±3.20	4.37±1.80	1.29	0.267	4	2.5984
	On	4.07±2.27	4.77±1.80	-3.73	0.02	4	2.0498

T-Value of the means of the two locations along the rows with P-Value less than 0.05 is significantly different (P < 0.05). Cg-*Clarias garipienus,* Cn- *Chrysichthys nigrodigitatus,* On- *Oreochromis niloticus*

DISCUSSION

The bacteriological status of fish is of importance to both the aquatic environment and fish consumers. In this instance, the bacterial load of three fish species from two locations was studied, and these obvious indicators show that different water bodies have different levels of bacteria (Cabral 2010; Some *et al*., 2021). This could probably be from the backdrop of the activities carried out by men in and around the water bodies. It was noticed at the time of this investigation that the lower River Benue in the Ibi local government area of Taraba State had fish with more bacterial load than the major tributary of River Benue in the Katsina-Ala local government area of Benue State. The fish bacterial load can cause severe fish economic losses due to post-harvest spoilage from bacteria activities, and in addition harm the consumers (Safaeian and Khanzadi, 2018; Mishra, Sudhansu, *et al*., 2019; Maldonado-Miranda et *al*., 2022; Keerthana *et al*., 2022; Ogura, 2022). The overview of this study is to compare and quantify the bacteria status of the three common fish species in these locations to raise the necessary awareness that would reduce anthropogenic activities or unhealthy fishing activities around and within this aquatic ecosystem. Therefore, it was noticed that the fish species in the two locations had similar patterns of bacteria loads on the various organs investigated, where the intestine had more bacterial loads and the skin and gills were trailing in that order. This perhaps could be because of the suitable substrate of the intestine for bacteria growth (Umma *et al*, 2023), and the more frequent interfacing of the gills and the skin with the flowing water. Furthermore, it was noticed that the bacteria loads of the intestine of *Clarias gariepinus* were significantly higher than that of *Chrysichthys nigrodigitatus* and *Oreochromis niloticus*, this could be due to the feeding habit of the selected fish species, where *Clarias gariepinus* is an omnivore, and also having the propensity for being carnivorous (Khedkar *et al*., 2002), although *Chrysichthys nigrodigitatus*, and *Oreochromis niloticus* may have an overlapping feeding habit of both omnivorous and herbivorous (Dada and Araoye, 2008), the primary feeding habit of *Oreochromis niloticus* is herbivore (Khallaf and Alne-na-ei 1987). However, the gills of *Oreochromis niloticus* had more bacterial loads compared to *Clarias gariepinus* and *Chrysichthys nigrodigitatus*. This could be because the gill of *Oreochromis niloticu*s tends towards being a good substrate for bacteria, as reported by Bakr *et al.* (2021) where the gills of *Oreochromis* *niloticus* showed more susceptibility to infection carried out by intraperitoneal injection of 0.1 ml of 1.5 x 10^8 CFU/ml of *A. sobria* than the skin. The skin of *Clarias gariepinus* was seen to have more bacterial loads than the skin of both *Chrysichthys nigrodigitatus* and *Oreochromis niloticus*. This is perhaps due to the nature of the skin where the slime though having a protecting tendency could also support bacteria growth. In general, the bacteria were at the range of 7.90– 4.30 CFU/g for the gills, 11.37– 6.88 CFU/g for the intestine and 6.55– 4.07 CFU/g for the skin of the three species of fish in the two locations while the acceptable maximum microbiological limits for total viable aerobic bacterial counts (TVABC) 5 x 10^5 CFU/g, and the acceptable limits of total coliform (TC) and fecal (FC) for fresh and frozen fish are < 100 most probable number per gram (MPN/g) and < 10 MPN/g respectively (ICMSF- International Commission of Microbiological Specification for Food, 1986).

CONCLUSION

In conclusion, the two Rivers from different sources had a common confluence point, signifying their link and the need for studying the bacterial diversity of the economic fish species from the two fish landing sites and also comparing their bacterial loads with the acceptable limits for human consumption. The fish collected from River Katsina-Ala landing site had less bacterial load than the fish collected from River Ibi landing site, however, still below the borderline of the acceptable limits. The obvious reason for the differences in fish bacterial loads in the two locations could be due to the nature of activities along the rivers and the handling methods from capture to the landing sites.

REFERENCES

Afigbo, A. E. (1997). "Southeastern Nigeria, the Niger-Benue Confluence, and the Benue in the Precolonial Period: Some Issues of Historiography" *History in Africa.* 24(4): 1-8.

Ama-Abasi, D., Udo, M., Uyoh, E.A., Job, B., Edide, J. and Uwalaka, S. (2019). The migration status of silver catfish, *Chrysichthys nigrodigitatus* (Siluriformes: Claroteidae) of the cross River, Nigeria. *International Journal of Fisheries and Aquatic Studies.* 7(5): 536-541.

Ama-Abasi, D., Uyoh E.A., Udo, M., Job, E. and Edide, J.E. (2017). Preliminary investigation on the migration pattern of silver catfish, *Chrysichthys nigrodigitatus* of the Cross River, Nigeria pp 261-263. *In*: K.E. Lelei (Ed), Proceedings of the Annual Conference of Fisheries Society of Nigeria Asaba, Nigeria. 460p

Bakr, M., Abdelmalek, S., Suloma, A., Awad, M. and Attia, S. (2021). Effect of Aeromonas sobria infection on gills and skin histopathology of the Nile tilapia reared under bio floc and clear water systems. *Egyptian Journal of Aquatic Biology and Fisheries.* 25(1): 933-950.

Cabral, J.P.S. (2010) Water Microbiology. Bacterial Pathogens and Water. *Int J Environ Res Public Health.* 7(10): 3657–3703

Cardoso, A.H, Carlos, A.P.L., Darbello, M.E. and Galembeck, Z. F. (1998). Easy polymer latex self-assembly and colloidal crystal formation: the case of poly [styrene-*co*-(2-hydroxyethyl methacrylate)]. *Colloids and Surfaces A: Physicochemical and Engineering Aspects.*144(1–3): 207-217

Dada, J.O. and Araoye, P.A. (2008). Some Aspects of the Biology of *Chrysichthys nigrodigitatus* (Pisces: Siluroidae) In Asa Lake Ilorin, Nigeria. *Nigerian Journal of Fisheries*. 5(1): 73-84.

Eissa, N.M., El-Ghiet, E.A., Shaheen, A.A. and Abbass, A. (2010) Characterization of Pseudomonas species isolated from tilapia "*Oreochromis niloticus*" in Qaroun and Wadi-El-Rayan lakes. *Egypt. Global Veterinaria.* 5(2): 116–121.

Emikpe, B.O., Adebisi, T. and Adedeji, O.B. (2011). Bacterial load on the skin and stomach of *Clarias gariepinus* and *Oreochromis niloticus* from Ibadan, Southwest Nigeria: Public health implications. *Journal of Microbial Biotechnology Research.* 1(1): 52–59.

Eyo, V.O., Ekanem, A.P. and Jimmy, U.I. (2014). A comparative study of the gonadosomatic index (GSI) and gonad gross morphology of African catfish (*Clarias gariepinus*) fed uncial aqua feed and Coppens commercial feed. *Croatian Journal of Fish*. 72(2): 63–69.

Eze, E.l., Echezona, B.C. and Uzodinma E.C. (2011). Isolation and identification of pathogenic bacteria associated with frozen mackerel fish (*Scomber scombrus*) in a humid tropical environment. *African Journal of Agricultural Research.* 6(7): 1918–1922.

Fagbuaro, O., Oso, J., Olurotimi, M. and Akinyemi, O. (2015). Morphometric and Meristic Characteristics of *Clarias gariepinus* from Controlled and Uncontrolled Population from Southwestern Nigeria. *Journal of Agriculture and Ecology Research International*. 2(1): 39-45.

Federal Department of Fisheries (2007). Fisheries Statistics of Nigeria, (4th Edition, p. 1995).

Holzloehner, S., Enin, U. I., Ama-Abasi, D. and Nwosu, F. M. (2007). Species composition and catch rates of the gillnet fishery in the central Cross River estuary, SE Nigeria. *J. Afrotrop Zool*., Special Edition, 107-112.

ICMSF (International Commission of Microbiological Specification for Food) *Microorganisms in Food 2. Sampling for Microbiological Analysis: Principles and Specific Applications*. 2nd. Toronto, Canada: University of Toronto Press; 1986.

Kapinga, I, Mlaponi, E. and Kasozi, N. (2014). Effect of stocking density on the growth performance of sex-reversed male Nile tilapia (*Oreochromis niloticus*) under pond conditions in Tanzania. *World Journal of Fish and Marine Sciences.* 6(2): 156–161.

Kar, J., Barrman, T.R., Sen, A. and Nath, S.K. (2017). Isolation and identification of *Escherichia coli* and Salmonella sp. from apparently healthy Turkey. *International Journal of Advanced Research in Biological Sciences.* 4(6): 72-78.

Keerthana, P.S., Soorya G., Rubeena R., Rinu F., Kavya S.N.R., Pooja U., Teena E., Gifty T, Arun Das N.H, Dinesh K, Safeena M.P and Sreekanth G.B. (2022). Post-harvest losses in the fisheries sector- facts, figures, challenges and strategies. *International Journal of Fisheries and Aquatic Studies*. 10(4): 101-108.

Khallaf, E.A. and Alne-na-ei, A.A. (1987). Feeding ecology of *Oreochromis niloticus* (Linnaeus) & *Tilapia zillii* (Gervais) in a Nile Canal. *Hydrobiologia*. 146(1): 57-62.

Khedkar, G.D., Jadhao B.V., Chavan N.V., Khedkar C.D. and Caballero B. (2003). *Demersal Species of Tropical Climates. Encyclopedia of Food Sciences and Nutrition, 2438-2442.*

Maldonado-Miranda, J.J., Castillo-Pérez, L.J., Ponce-Hernández, A. and Carranza-Alvarez, C. (2022). Chapter 19-Summary of economic losses due to bacterial pathogens in the aquaculture industry. *In*: Dar G.H. *et al*. (Eds.). Bacterial Fish Diseases. Academic press. .399-417.

Mandal, S.C., Hasan, M.S., Rahman, M.H. Manik, Z.H. Mahmud and M.S. Islam. (2009). Coliform Bacteria in Nile Tilapia, *Oreochromis nilotiIcus* of Shrimp-Gher, Pond and Fish Market. *World Journal of Fish and Marine Science.* 1(3): 160-166.

Meijide, F.J., Da Cuna, R.H., Prieto, J.P., Dorelle, L.S., Babay, P.A. and Lo Nostro, F.L. (2018). Effects of waterborne exposure to the antidepressant fluoxetine on swimming, shoaling, and anxiety behaviors of the mosquito fish Gambusia holbrooki. *Ecotoxicology and Environmental Safety*, 16: 646–655.

Mishra, S., Das, R. and Swain, P. (2019) Status of Fish Diseases in Aquaculture and assessment of economic loss due to disease. *In* book: Contemporary Trends in Fisheries and Aquaculture. Today & Tomorrow's Printers and Publishers, New Delhi, India, 183-198.

Mohanty, B., Mahanty, A., Ganguly, S., Sankar T.V, Chakraborty, K., Rangasamy, A., Paul, B., Sarma, D., Mathew, S., Asha, K.K., Behera, B., Aftabuddin, M., Debnath, D., Vijayagopal, P., Sridhar, N., Akhtar, M.S., Sahi, N., Mitra, T., Banerjee, S., Paria, P., Das, D., Das, P., Vijayan, K.K., Laxmanan, P.T. and Sharma, A.P. (2014). Amino Acid compositions of 27 food fishes and their importance in clinical nutrition. *J. Amino Acids.* 2014: 269797

Mortuza, M.G, Al-Misned F.A. (2013). Length-weight relationships, condition factor and sex-ratio of Nile tilapia, *Oreochromis niloticus* in Wadi Hanifah, Riyadh, Saudi Arabia. *World Journal of Zoology*. 8(1): 106–109.

Murthy, L.N. and Jeyakumari, A. (2019). Post mortem biochemical changes in fish. *Mumbai Research Centre of ICAR-Central Institute of Fisheries Technology*, Vashi, India.

Ogura, S. (2022). Pathogenic bacteria load and safety of retail marine fish. *Brazilian Journal of Biology*. 82: e262735

Olugbojo, J.A. and Ayoola, S.O. (2015). Comparative studies of bacteria load in fish species of commercial importance at the aquaculture unit and lagoon front of the University of Lagos. *International Journal of Fisheries and Aquaculture*. 7(4): 36–46.

Sapkota, R.P., Brunet, A. and Kirmayer, L.J. (2020). Characteristics of Adolescents Affected by Mass Psychogenic Illness Outbreaks in Schools in Nepal: A Case-Control Study. *Frontiers in Psychiatry*. 11(1): 1271.

Sara, S. and Saeid, K. (2018). Microbiology of Fish and Seafood. The 1st national conference on recent advances in Engineering and modern sciences, 11 March 2018/ Tehran – Iran, IRIB International Conference Center

Schmeller, D.S., Loyau, A., Bao, K., Brack, W., Chatzinotas, A. and De Vleeschouwer, F.

(2018). People, pollution and pathogens– Global change impacts in mountain freshwater ecosystems. *Science of the Total Environment.* 62(1): 756–763.

Shields, P. and Laura, C.L. (2010). Oxidase Test Protocol. A peer-reviewed at the ASM Conference for Undergraduate Educators 2010. *American Society for Microbiology.*

Some, S., Mondal, R., Mitra, D., Jain, D., Verma, D. and Das, S. (2021). Microbial pollution of water with special reference to coliform bacteria and their nexus with the environment.VL-1C. DO-10.1016/j.nexus.2021.100008.

Sue Katz, D. (2008). "The Streak Plate Protocol" pp 1-14. *In:* Alderson G. *et al*. (Eds). Proceedings of the 15TH Annual Conference of the *American Society for Microbiology (ASM*) for Undergraduate Educators, Endicott College, Beverly, MA, USA.

Svanberg, I. (2021). The importance of animal and marine fat in the Faroese cuisine: the past, present, and future of local food knowledge in an island society. *Frontiers in Sustainable Food Systems.* 5: 599476.

Tacon, A., Lemos. D. and Metian, M. (2020). Fish for Health: Improved Nutritional Quality of Cultured Fish for Human Consumption. *Reviews in Fisheries Science & Aquaculture*. 28(4): 1-10.

Tsadik, G.G. and Bart, A.N. (2007). Effects of feeding, stocking density and water-flow rate on fecundity, spawning frequency and egg quality of Nile tilapia, *Oreochromis niloticus*. *Aquaculture.* 275(1): 152–162.

Umma, S.B., Iyiola, A.O. and Adeshina, I. (2023). Relationship pattern of enteric bacterial load and assessed micronutrients in the gut of *Clarias gariepinus* fish sampled in the Ibadan municipal zone. *JoBAZ.* 84 (23): 1-13.

Uyoh, E.A., Ntui, V.O., Ibor, O.R., Adilieje, C.M., Udo, M., Opara, C., Ubi, G. and Ama-Abasi, D. (2020). Molecular Characterization of Two Catfish Species (*Chrysichthys nigrodigitatus* and *Chrysichthys auratus*) from the Cross River, Nigeria, Using Ribosomal RNA and Internal Transcribed Spacers. *Annual Research & Review in Biology*. 35(2): 13-24.

Vanamala, P., Sindhura, P., Sultana, U., Vasavilatha, T., Gul, M.Z. Dar, G.H., Bhat, R.A., Qadri, H., Al-Ghamdy, K.M. and Hakeem, K.R. (2022). *Common bacterial pathogens in fish: An overview.* In Bacterial Fish Diseases, p279-306, Academic Press.

Váradi, L., Jia, L.L, David, E.H., John, D.P., Rosaleen, J.A., Sylvain, O. and Paul, W.G. (2017). Methods for the detection and identification of pathogenic bacteria: past, present, and future. *Chem. Soc. Rev.*, 46 (1): 4818-4832.

Wang, C., Chuprom, J., Wang, Y. and Fu, L. (2019). Beneficial bacteria for aquaculture: nutrition, bacteriostasis, and immunoregulation. *Journal of Applied Microbiology*. 129 (1):28-40.

WHO (2007): Food safety issues associated with products from Aquaculture. Report of a Joint FAO/NACA/WHO study Group, WHO Technical reprint Series: 883 + Geneva.

Zhu, S., Zhang, Z. and Zagar, D. (2018). Mercury transport and fate models in aquatic systems: A review and synthesis. *Science of the Total Environment*. 63(1): 538–549.

Ziarati, M., Zorriehzahra, M.J., Hassantabar. F., Mehrabi, Z., Dhawan, M., Sharun, K., Emran, T.B., Dhama, K., Chaicumpa, W. and Shamsi, S. (2022). Zoonotic diseases of fish and their prevention and control. *Vet Q*. 42 (1): 95-118.

COMMUNITY STRUCTURE OF CICHLIDS IN SOME MAJOR LAKES IN NIGERIA

[*1]ADEDEJI, H. A., [1] T. A., IDOWU, [2] R. Y. OLADUNJOYE, AND [1]O. A. SOGBESAN
[1]Department of Fisheries, Modibbo Adama University, Yola
[2]Department of Zoology and Environmental Biology, Olabisi Onabanjo University, Ago-Iwoye
Corresponding Author: bowaledeji@mau.edu.ng

ABSTRACT
The study was conducted to investigate the status of the Cichlidae family in some major lakes of Nigeria namely; Asejire, Oyan, Geriyo, Dadin-Kowa, Kainji, and Jebba. Samples of the cichlid group were collected bi-monthly from the study sites for six months, between July and December 2016. During the study, a total of 6,583 individuals were observed, belonging to seven species, including Coptodon zillii, Pelmatolapia mariae, Sarotherodon galilaeus, Oreochromis niloticus, Chromidotilapia guntheri, Hemichromis fasciatus, and Hemichromis bimaculatus. The highest composition of the six species and abundance, except for H. bimaculatus, was found in Asejire and Oyan lakes, followed by Kainji and Jebba lakes, which had a composition of five species, except for P. mariae and H. bimaculatus. Geriyo and Dadin-Kowa lakes had species compositions of four and three respectively. The study revealed that the species abundance was higher during the wet season, but still reasonable during the dry season, except for H. bimaculatus, which was generally low where it was observed. It was also observed that O. niloticus was dominant in abundance in four study locations compared to S. galilaeus which was dominant in two locations. Shannon-Weiner's diversity indices indicated that Asejire and Oyan lakes were more diverse and richer in cichlid group, while Geriyo and Dadin-Kowa lakes were less diverse and less rich in cichlid group. Similarly, Pielou's evenness showed that the cichlid group of Dadin-Kowa Lake is more even in their abundance than from other sites while the Simpson diversity index was higher in Asejire and Oyan compared to other studied sites.

Keywords: Asejire Lake, Cichlid Group, Composition and Abundance, Diversity Indices, Kainji Lakes

INTRODUCTION

Conservation and management of natural resources of any nation are crucial to the sustainable development of that nation; and among these arrays of natural resources are the aquatic resources, which include freshwater, brackish and marine resources (Ekpo and Essien-Ibok, 2013). Fishing has been a major source of food for humanity, employment opportunities and economic benefits to those engaged in it. However, with increased knowledge and dynamic in fisheries development, it was realized that living aquatic resources, although renewable, are not infinite and need to be properly managed, if their contribution to the nutritional, economic and social well-being of the growing world's population was to be sustained (Kocher, 2004; Ekpo and Essien-ibok, 2013). The decline in global fish production in recent years which is been brought about by overfishing and continuing environmental degradation called for improved proper management schemes and sustainable utilization of aquatic resources.

Tilapia group of the family cichlid is of major importance to artisanal fisheries in Africa (Kocher, 2004) and their widespread introduction has led to the establishment of tilapia fisheries in areas in which they were not native (Blanco *et al*., 2007) or not historically an important component of the catch (Balirwa, 1992) They have also been reported to be critically important to world aquaculture, as attested to by the reports of Costa-Pierce and Rakocy, (1997) and Fitzsimmons, (1997). Over the years, the compositions and abundance of total fish species in lakes, ponds, rivers etc have been researched by different researchers which include but are not limited to the work of Yem, *et al*. (2011) from different water bodies in Nigeria, Olapade and Rufau (2014) from Oyan Lake, Oyo State, Olufeagba, *et al*. (2015) from Kainji Lake, Niger State, Falaye, *et al*. (2015) from Erelu Lake, Oyo State, Zira, *et al*. (2017) from Kiri Dam, Adamawa State, Adedeji, *et al*. (2017) from Ribadu Lake, Adamawa State, Sani, *et al*. (2019) from Bonda River, Kwali Area Council, Abuja, Essien-Ibok and Isemin (2020) from major water bodies in Akwa-Ibom State, Nazeef *et al.* (2021) from Dadin-Kowa Lake, Gombe State.

However, only a few of these ichthyofauna studies pay special attention to the cichlid group having been reported to constitute about thirty percent of the fish composition of any environment they occupy (Adeyemi *et al*., 2010; Adaka *et al*, 2014; Adedeji *et al*. 2017). Due to the importance of this group of fish to aquatic ecosystem structure and function, fisheries and aquaculture, it is critically important to study their diversity and abundance in some major lakes in Nigeria for effective and efficient management and conservation of the cichlidae. The objectives of the study were to determine the compositions and community structures of cichlids from the selected major Lakes in Nigeria using some ecological diversity indices,

MATERIALS AND METHODS

Characteristics of the study locations

Asejire Lake: Asejire Lake is a man-made lake that was constructed over River Oshun in 1972 and lies on latitude 07º 2ˈN and longitude 04º 07ˈE. It is located about 30 km east of Ibadan, Oyo State, Nigeria. The lake is Y-shaped with two unequal arms of the Y. Catchment area above the dam is 7,800 km^2 and the impounded area is 2,342 hectares (Ayoade *et al*., 2006). The lake has a gross storage capacity of 7,403 million litres of water with an elevation of 137 m. It has a relative humidity of 73.4 - 79.1, transparency range between 0.7 - 1.72 m, surface water temperature of 24 - 31.5°C, dissolved oxygen 5.1 - 8.9 mgL^{-1} and pH 6.2 - 8.5 (Ayoade *et al*., 2006).

Oyan Lake: This is also a man-made lake constructed on the Oyan River in 1983 with an estimated average annual flow of about 1,770 million. It lies on latitude 07º 15ˈN and longitude 03º16ˈE. It covers 4,000 hectares and has a catchment area of 9,000 km^2. It has an average length of 1044m, height of 30.4m with an elevation of 150m above the sea level. Average annual temperature and rainfall are 24.3ºC and 102.6 mm respectively with a total capacity of about 270 million (Ayoade *et al*., 2006).

Lake Geriyo: It is a floodplain lake, located on the outskirts of Jimeta metropolis, Adamawa in North-western Nigeria. It lies between latitude 9° 18'N and longitude 12° 25'E. It is a shallow water body with a mean depth of about 2 meters and the mean annual rainfall is between 900 to 1100mm with the rainy season ranging from 150 – 160 days, usually from May to October. Temperature ranges from 20°C in December to January and intense heat with temperatures of 30°C to 42°C from March to April (Upper Benue River Basin Development Authority, 1985). It experiences some influx of water from floods during the rainy season and overflows from river Benue which serves as a major water source to the lake.

Dandin-kowa Lake: A man-made lake that is located 5km North of Dadin Kowa village (about 37km from Gombe town, along Gombe-Biu road) in Yamaltu Deba Local Government Area of Gombe State. The area lies within latitude 10º18ˈN and longitude 11º32ˈE of the equator. The lake has a water capacity of 800 million cubes and a surface area of 300 kilometers square (Upper Benue River Basin Development Authority, 1980).

Kainji Lake: This is a reservoir on the Niger River, formed by the Kainji Dam. It lies on the latitude 10º22ˈN and longitude 04º32ˈEof the equator. The Kainji Lake basin is one of the most important inland basins in Nigeria, it is the home of the first and the largest hydro-electricity station in the country, and the woodland vegetation of the basin is the home of the first National Parks in Nigeria (Ikusemoran and Olokor, 2014). According to Ikusemoran and Adesina (2009), the impoundment of Kainji Lake on the River Niger has converted the river into a lake ecosystem and has also changed the land cover around the formed lake.

Jebba Lake: The lake lies between longitude 04º30ˈto 04º50ˈE and latitude 09º55ˈN (Figure 4). It has a drainage basin extending from Kainji Reservoir to the Jebba area (approximately 100 km). The six major rivers that empty into the lake are Oli, Wuruma, Moshi, Awuru on the western side and Kontangora and Eku on the Eastern part (Adesina *et al.* 2007).

Collection and Identification of Samples

The samples from Asejire and Dadin-kowa Lakes were collected at the dam site of the lake, while samples from Oyan Lake were collected at the Abule titun landing site which is very close to the dam site. Samples from Geriyo Lake were collected at the landing site of the lake while samples from Kainji and Jebba Lakes were collected at the Monai village landing site and New Awuru landing site respectively. Identification of the cichlid species was done using the field guide to Nigerian Freshwater Fishes (Revised Edition) by Olaosebikan and Raji (2013). Routine sampling was conducted and specimens of cichlid species were collected bi-monthly for six months between July and December 2016 from the catches of three contracted artisanal fishermen from each study location using gill nets of various mesh sizes ranging from 30mm to 80mm

Data analysis

Composition and abundance were presented in tables while three different ecological indices were used to describe the diversity of Cichlids in each of the studied reservoirs. These include:

Relative species abundance % =
Which refers to the relative representative of a particular species and was determined by dividing the number of species (n) from each catch by the total number of species (N) from the total catch recorded

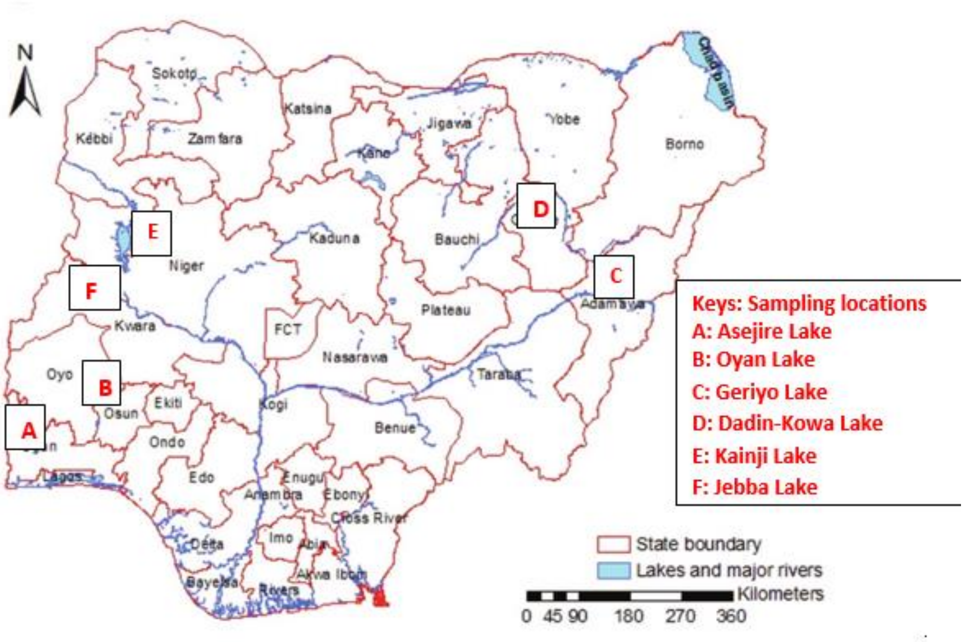

Figure I. Map of Nigeria showing the study locations

Margalef's index (D) for species richness (Margalef, 1968)

D - $(S-1)/\ln(N)$

Where S is the number of species

N is the number of individual

Shannon Weiner's Index (H') of species diversity (Shannon and Weiner 1963):

H'= $\sum(PiLnPi)$

Where Pi = the proportion of the total number of individuals occurring in species i, while $LnPi$' is the natural logarithm of this proportion

Simpson's index: d = $\sum\ (n(n-1) \div N(N-1))$

Where n = number of individuals of a particular species and N = the total number of individuals present in the entire sample.

Simpson's index of diversity = $(1-d)$

Pielou's Index (J) for species evenness (Pielou 1969):

J = $H \div LnS$

Where H' is the species diversity index (Shannon wiener) and S is the number of species/species richness.

The three different ecological indices were analyzed using Microsoft excel (2010) package

RESULTS

Species Composition and Abundance

The compositions and relative abundance of cichlids from five major reservoirs in Nigeria during the sampling period are presented in Table 1. The results showed that a total of six thousand, five hundred and eighty-three individuals (6583) were sampled during the study which belong to different seven species of cichlids, which include *Coptodon zilli, Pelmatolapia mariae, Sarotherodon galilaeus, Oreochromis niloticus, Chromidotilapia guntheri, Hemichromis fasciatus* and *Hemichromis bimaculatus* (Figure I). Asejire and Oyan reservoirs had the highest number of species compositions of six (6) each followed by Kainji, Jebba and Geriyo Lakes with species composition of five (5) while

Dadin-Kowa lake had the least species composition of three (3) (Table 1). *C. zilli*, *S. galilaeus* and *O. niloticus* were the most common species in all the studied locations while *P. mariae* were only observed in Asejire and Oyan Lakes. Similarly, *H. fasciatus* was also common in all the studied locations except in Dadin-Kowa Lake where it was absent while *C. guntheri* was also observed in all the studied locations except in Geriyo and Dadin-kowa Lakes. *H. bimaculatus* was only observed in Geriyo and absent in other studied locations.

The results also revealed that Asejire Lake had the highest species abundant of cichlids with one thousand, four hundred and six (1406) individuals which accounted for 21.36% of the total individuals sampled and was followed by Oyan Lake, with a total species abundant of cichlid species of one thousand, two hundred and ninety-four (1294) individuals and accounted for 19.66% of the total samples observed. (Table II). Kainji and Jebba lakes had species abundant of one thousand, two hundred and twenty-one (1221) and one thousand, and thirty-three (1033) which represented 18.55% and 15.69% respectively of the total samples observed while Geriyo had eight hundred and seventy (870) of species abundant and accounted for 13.22%. Dadin-Kowa had the least total species abundant of cichlids of seven hundred and fifty-nine (759) that represented 11.53% of total observed individuals. The results also revealed that the highest species abundance was observed in August with a total of 1284 individuals followed by July and September with a total of 1251 and 1164 individuals respectively. The lowest species abundance was observed in October with 871 individuals followed by November with 960 individuals while a total of 1053 was observed in December.

Species Diversity indices

The results showed that Asejire and Oyan Lakes had the highest species richness indices (Margalef index) of 0.568 each followed by Geriyo, Kainji and Jebba Lakes with 0.455 values each while the Dadin-Kowa Lake had the lowest species richness index of 0.227. The diversity indices of the five major lakes in Nigeria also showed that Asejire and Oyan lakes had the highest values of 1.743 and 1.725 respectively for Shannon-Weiner while Dadin-kowa Lake had the lowest value of 1.098 for Shannon-Weiner. The values of 1.203, 1.519 and 1.501 were observed from Geriyo, Kainji and Jebba lakes for Shannon-Weiner. Similarly, the highest value for Pielou's evenness (0.999) was observed from Dadin-Kowa Lake followed by Asejire (0.973) and Oyan (0.963) lakes. The lowest evenness value (0.747) was observed in Geriyo Lake. The Simpson index of diversity showed that Asejire and Oyan lakes had the highest values of 0.818 and 0.812 respectively while the Geriyo Lake had the lowest value of the Simpson index of diversity of 0.683. Kainji and Jebba Lake had values of 0.768 and 0.762 respectively.

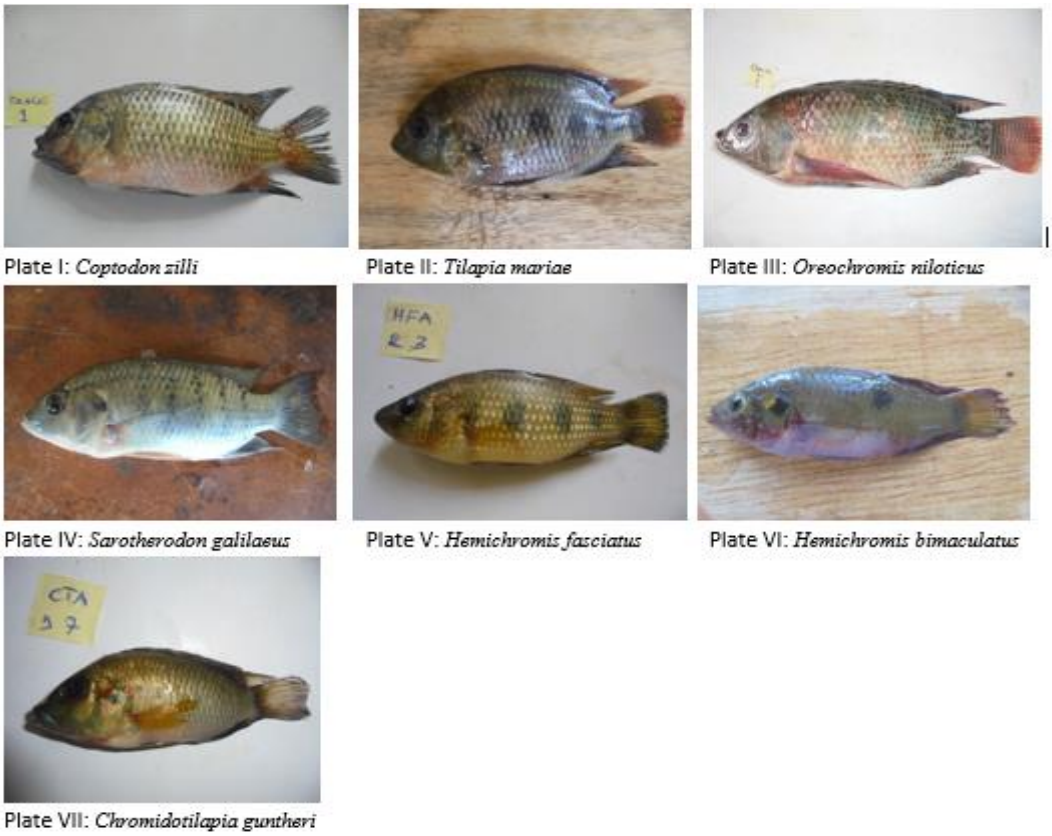

Figure II: Samples of cichlid species encountered during the study

Table 1: Species composition and abundance of cichlids group from five major lakes in Nigeria between July and December, 2016

		Asejire	Oyan	Geriyo	Dadin-Kowa	Kainji	Jebba	
JULY	*C. zilli*	55	52	45	36	58	47	
	P. mariae	41	32					
	S. galileaus	61	63	51	42	62	51	
	O. niloticus	56	52	47	45	63	54	
	C. guntheri	35	21			25	21	
	H. fasciatus	31	36	6		37	21	
	H. bimaculatus			5				
Sub-Total		**279**	**256**	**154**	**123**	**245**	**194**	**1251**
AUGUST	*C. zilli*	59	56	48	43	61	49	
	P. mariae	43	37					
	S. galileaus	61	59	55	46	61	53	
	O. niloticus	60	54	51	49	65	51	
	C. guntheri	33	24			22	22	
	H. fasciatus	26	31	5		34	24	
	H. bimaculatus			2				
Sub-Total		**282**	**261**	**161**	**138**	**243**	**199**	**1284**
SEPTEMBER	*C. zilli*	52	51	47	41	54	50	
	P. mariae	39	31					

	S. galileaus	54	51	53	45	57	51	
	O. niloticus	53	49	52	46	60	52	
	C. guntheri	29	21			16	14	
	H. fasciatus	21	24	3		29	19	
	H. bimaculatus							
Sub-Total		**248**	**227**	**155**	**132**	**216**	**186**	**1164**
OCTOBER	*C. zilli*	40	38	37	40	44	36	
	P. mariae	25	21					
	S. galileaus	40	42	43	38	41	40	
	O. niloticus	45	37	41	40	42	41	
	C. guntheri	10	8			10	8	
	H. fasciatus	21	17			16	10	
	H. bimaculatus							
Sub-Total		**181**	**163**	**121**	**118**	**153**	**135**	**871**
NOVEMBER	*C. zilli*	38	41	40	42	50	40	
	P. mariae	31	25					
	S. galileaus	43	46	50	43	47	42	
	O. niloticus	46	40	43	39	49	46	
	C. guntheri	17	12			10	10	
	H. fasciatus	20	18			19	13	
	H. bimaculatus							
Sub-Total		**195**	**182**	**133**	**124**	**175**	**151**	**960**
DECEMBER	*P. mariae*	36	28					
	S. galileaus	46	45	52	41	51	46	
	O. niloticus	50	42	49	43	52	50	
	C. guntheri	21	17			14	11	
	H. fasciatus	23	25	1		21	18	
	H. bimaculatus							
Sub-Total		**221**	**205**	**146**	**124**	**189**	**168**	**1053**
Grand Total		**1406**	**1294**	**870**	**759**	**1221**	**1033**	**6583**

Table II: Relative Abundance and Percentage Compositions of Cichlid Group of the Lakes in Nigeria

July - Dec	Asejire (%)	Oyan (%)	Geriyo (%)	Dadin-Kowa (%)	Kainji (%)	Jebba (%)	TOTAL
C. zilli	289 (20.55)	286 (22.10)	261 (30)	242 (31.88)	318 (26.04)	265 (25.65)	1661(25.23)
P. mariae	215 (15.29)	174 (13.45)					389(5.91)
S. galileaus	305 (21.69)	306 (23.65)	304 (34.94)	255 (33.60)	319 (26.13)	283 (27.40)	1772(26.92)
O. niloticus	310 (22.05)	274 (21.17)	283 (32.53)	262 (34.52)	331 (27.11)	294 (28.46)	1754(26.64)
C. guntheri	145 (10.31)	103 (7.96)			97 (7.94)	86 (8.33)	431(6.55)
H. fasciatus	142 (10.10)	151 (11.67)	15 (1.72		156 (12.78)	105 (10.16)	569(8.64)
H. bimaculatus			7 (0.81)				7(0.11)
Composition %	21.36%	19.66%	13.22%	11.53%	18.55%	15.69%	
TOTAL	**1406**	**1294**	**870**	**759**	**1221**	**1033**	**6583**

Table III: Diversity indices of Cichlid group from some major lakes in Nigeria

	Asejire	Oyan	Geriyo	Dadin-Kowa	Kainji	Jebba
No of Species	6	6	5	3	5	5
No of Individuals	1406	1294	870	759	1221	1033
Margalef	0.569	0.569	0.455	0.227	0.455	0.455
Shannon-Weiner	1.743	1.725	1.203	1.098	1.519	1.501
Evenness	0.973	0.963	0.747	0.999	0.944	0.932
Simpson	0.818	0.812	0.683	0.667	0.768	0.762

DISCUSSION

Cichlids are known for evolving rapidly into many closely related but morphologically diverse species within lakes (Meyer, 2005). The best-known genera in Nigeria are Tilapia (Fagade and Olaniyan, 1971), Hemichromis (Fagade 1983) and Sarotherodon which was reported by Trewavas (1983) and conformed to this study. Several researchers have worked on the composition of cichlids in some water bodies in Nigeria which include Morenikeji and Adepeju (2009) who reported six (6) species from Eleyele Dam, Olubunmi *et al*. (2017) and Simon-Oke (2017) reported five (5) and four (4) species from the same lake respectively. Yem *et al.* (2011) reported seven (7) species from Oguta Lake, three (3) species from Dadin-Kowa Lake, eight (8) species from Asejire and Oyan, four (4) species from Asa River and Tiga Lake and two (2) species from Opi River. Olapade and Rufai (2014) documented five species of cichlids from Oyan Dam while Olufeagba *et al.* (2015) reported four species of cichlids from Kainji Lake. Six (6) species were reported by Falaye *et al.* (2015) from Erelu Lake in Oyo State. Zira *et al.* (2017) observed three (3) species from Kiri Dam while Dan-Kishiya *et al.* (2013) reported four (4) species from Lower Usuma reservoir, Bwari Abuja. Sogbesan *et al*. (2017) documented three (3) species from Lake Geriyo and Upper River Benue while Salele *et al*. (2023) reported four (4) species from Zobe reservoir, Dutsin-ma, Kastina State.

The six species of the cichlid group identified in this study from Asejire Lake is lower than that of Yem et al. (2011) who reported eight species from the same study site as this present study did not observe Pelmatochromis guntheri and Tilapi a dageti. However, this study observed higher species composition than the work of Ipinmoroti (2013) who recorded C. zillii, S. galilaeus and O. niloticus from Asejire lake. Yem et al. (2011) observed T. melanopleura, T. macrocephala and T. monody from Oyan Lake which were not found in this study. Although, their reports did not include C. guntheri that was identified in the study. Olapade and Rufai (2014) documented five species of cichlid group that include those documented in the present study except C. guntheri. The differences in the observed species from Oyan Dam could be attributed to the differences in the sampling locations because Olapade and Rufai (2014) sampled Imala and Ibaro communities while Abule tuntun and Ibaro were the study sampling sites. Meanwhile, Yem et al. (2011) did not specify the sampling site in their study but presumed to be the dam site. Another possible reason that could be responsible for the variation in species compositions in Oyan Dam could be the seasonal floods which Olapade and Rufai (2014) attributed to the low diversity of cichlids observed in their findings.

The three species (*C. zillii, O. niloticus* and *S. galilaeus*) observed in the Dadin-kowa Lake were the same species reported by Yem *et al*. (2011) and Nazeef *et al*. (2021) from the same Lake. In Lake Geriyo, Ekundayo *et al.* (2014) documented one species (*C. zillii*), while Adedeji *et al.* (2017) and Sogbeasn *et al*. (2017) reported three species (*C. zillii, O. niloticus* and *S. galilaeus*) compared to the six species observed from the present study. These differences could be associated with the sampling period (Adedeji *et al*. 2017), duration (Anene, 2005), sampling efforts (Olapade and Rufai, 2014) and possibly flooding from the adjacent Upper Benue River. Though, Ekundayo *et al.* (2014) sampled for a month, Adedeji *et al.* (2017) sampled for six (6) months while Sogbesan *et al*. (2017) did not specify the duration of their study. Another possible reason for the differences observed from previous studies compared to the present study in Lake Geriyo may be due to the fishing efforts as this present study sampled from the catches of three contracted artisanal fishermen. It is very important to note that the present study is the first to report the presence of *H. bimaculatus* in Geriyo Lake even though the abundance was very low and only observed during the middle of the wet season. In Kainji, *H. fasciatus* and *C. guntheri* are additional two species reported in this study in comparism to the work of Olufeagba *et al*. (2015) on the same lake where the authors recorded only *O. niloticus*, *C. zillii*, *T. marie* and *S. gailiaeus*.

The seasonal variation observed in this present study is in agreement with the findings of Olapade and Rufai (2014) who documented a similar trend in their study which indicated that the abundance of cichlid groups is higher in the wet season than dry season when compared. However, the presence of these cichlids group in both seasons described their abundance and diversity, which could be attributed to their natural history and traits such as high reproductive rates, high rate of juvenile and adult survival and strong competitive abilities that allow them to dominate other species (Van Dyke 2003).

The higher abundant of *O. niloticus* among the cichlids recorded in four out of the six study sites was a bit divergent from the submission of Adesulu and Sydenham (2007) and Olapade and Rufai (2014) that *S. galilaeus* is the most dominant and abundant species among the group in Nigerian freshwater. The diversity index, Shannon-Weiner observed in this present study was fairly higher than that of the report of Olapade and Rufai (2014) from Oyan Dam except that of Geriyo Lake (1.203) and Dadin-Kowa Lake (1.098) (2.483) with fairly low diversity of the cichlid group. The Simpson's index of diversity that ranges from 0.667 in Dadin-kowa Lake to 0.818 in Asejire Lake showed a very fair diversity in the studied areas which falls within the range reported by Adedeji *et al.* (2017) from Lake Geriyo, Adamawa State and Olapade and Rufai (2014) from Oyan Lake. The value usually ranges from 0 to 1 with greater value indicating greater diversity and index value which suggests that every two individual fish samples of the cichlid group that is randomly selected from each studied area will belong to different species. All the diversity indices in the present study with the exception of evenness are lower to the report of Adaka *et al.* (2014) who reported fair higher diversity indices of 9.007 for Margalef index, 2.965 for Shannon-weiner index and 0.940 for Simpson's index of diversity from Oramiri-Ukwa River, Southeast Nigeria. Lawson and Olusanyan (2010) also reported a higher Shannon-weiner index (2.015), a similar range of Simpson's index of diversity (0.845) and a lower evenness (0.74) from Igbesa tributary of River Ore, Ogun State. The report of Adedeji *et al*. (2017) also indicated a higher Shannon-weiner index (2.483) and Sinpson\s index of diversity (0.879) to the present study. However, the higher margalef index observed in Adaka *et al*.(2014) and Shannon-weiner in Lawson and Olusanya (2010) and Adedeji *et al.*(2017) compared to the present study may be connected to the facts that this present study only considered the cichlid species of the studied major Lakes while Adaka *et al*.(2014), Lawson and Olusanya (2010) and Adedeji *et al*.(2017) considered the whole species of their studied water bodies.

CONCLUSION

The results from the study revealed that Asejire and Oyan Lakes are composed of more cichlid species (six species), followed by Kainji and Jebba Lakes (5 species each) while Geriyo and Dadin-Kowa are composed of four and three cichlids species respectively. It also revealed that *C. zillii*, *O. niloticus* and *S. galilaeus* are the most common species in all the Lakes while *P. mariae* was only common to Asejire and Oyan Lakes. *H. fasciatus* and *C. guentheri* were only common to Asejire, Oyan, Kainji and Jebba Lakes while *H. bimaculatus* was only present in Geriyo Lake. Almost all the species were present both in the wet and dry seasons in all the study sites except *H. bimaculatus* which was only present towards the peak of the wet season. The various diversity indices observed across the study sites is an indication of fair diversity and distribution of the cichlid group and the very low abundance of *H. bimaculatus* in only one location and absence in others is a serious sign of their threatened and endangered status, which required immediate and necessary attention.

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REFERENCES

Adaka, G.S., Udoh, J.P., Onyeukwu, D.C. (2014) Freshwater Fish Diversity of aTropical Rainforest River in Southeast Nigeria. Advances in Life Science and Technology 23: F16-24.

Adedeji, H.A., Adeniyi, T.I., Olubunmi, A.J. and Amos, S.O. (2017). Some Ichyofauna Status of Lake Geriyo, Adamawa State. *Journal of Fisheries and Livestock Production*, Vol 5(3): 1-5 doi: 10.4172/2332-2608.1000244

Adesulu, E.A. and Sydenham, D.H.J. (2007). The Freshwater Fishes and Fisheries of Nigeria. Macmillan Nigeria Publishers, Lagos.

Adeyemi, S.O., Akombu, P.M. and Adikwu, I.A. (2010). Diversity and abundance of fish species in gbedikere lake, bassa, kogi state. *Journal of Research in Forestry, Wildlife and Environment.* 2(1):1 – 6.

Anene, A. (2005). Condition Factor of Four Cichlid Species of a Man-made Lake in Imo State, Southeastern Nigeria, *Turkish Journal Fish Aquatic Science*, 5, 43–47

Ayoade, A.A., Fagade, S.O. and Adebisi, A.A. (2006). Dynamics of limnological features of two-made lakes in relation to fish production. *African journal of Biotechnology*, 5: 1013-1021

Azionu, B.C., Ovie, S.I., Adigun, B. and Atiribom, B.Y. (2005). Prospects and Problems of Nigerian Inland Capture Fisheries: The Dimension of Sustainability. Fisheries Society of Nigeria, Book of Abstracts, pp: 49

Balirwa, J.S. (1992). The evolution of the fishery of *Oreochromis niloticus* (Pisces: Cichlidae) in Lake Victoria. *Hydrobiologia*, 232:58-89

Blanco, M.A., Carnevali, G., Whitten, W. M., Singer, R. B., Koehler, S., Williams, N., Ojeda, I., Neubig, K.M. and Endara, L. (2007). Generic realignments in Maxillariinae (Orchidaceae). *Lankesteriana* 7:515–537.

Costa-Pierce, B.A. and Rakocy, J. (1997). *Tilapia Aquaculture in the Americas*. Volume 1. World Aquaculture Society Books, Baton Rouge, Louisiana, United State

Dan-kishiya, A.S., Olatunde, A.A. and Balogun, J.K. (2013). Ichthyofauna Composition and Diversity of a Tropical Water Supply Reservoir A Case Study of Lower Usuma Reservoir In Bwari, Abuja, Nigeria. *American Journal of Research Communication*, 1: 188-203.

Ekpo, I.E. and Essien-Ibok, M.A. (2013). Development, prospects and challenges of artisanal fisheries in akwa Ibom state, Nigeria. *International Journal of Environmental Science, Management and Engineering Research*, 2 (3): 69-86.

Ekundayo, T.M, Sogbesan, O.A. and Haruna, A.B. (2014). Study of fish exploitation pattern of Lake Geriyo, Yola, Adamawa State, Nigeria. *Journal of Survey in Fisheries Sciences* 1: 9-20.

Essien-Ibok M A. and Isemin NL (2020) Fish species diversity, abundance and distribution in the major water bodies in Akwa Ibom state, *Nigeria. Biodiversity International Journal* 4(1):42–48

Fagade, S.O. (1983). The biology of *Chromidotilapia guentheri* from a small lake. *Arch Hydrobiologia* 97: 60-72.

Fagade, S.O. and Olaniyan, C.I.O. (1971). The food and feeding interrelationship of fishes of Lagos lagoon. *Journal of Fish Biology* 5: 205-225

Falaye, A.E., Ajani, E.K., Kareem, O.K. and Olanrewaju, A.N. (2015). Assessment of Ichthyofaunal Assemblage of Erelu Reservoir, Oyo, Nigeria. *Ecologia*, 5: 43-53. *DOI:*10.3923/ecologia.2015.43.53

Fitzsimmons, K. (1997). Future trends of tilapia aquaculture in the Americas. *In Tilapia Aquaculture in the Americas*. Costa-Pierce, B.A and Rakocy, J. E. (Eds) Vol. 2. The World Aquaculture Society, Baton Rouge, Louisiana, United States. pp.252–264

Ikusemoran, M. and Adesina, O. (2009). Landuse and Landcover Change Detection of Jebba Lake Basin, Nigeria: Remote Sensing and GIS Approach. University of Benin, Nigeria. *Knowledge Review Multidisciplinary Journal*, 18(1): 122-132

Ikusemoran, M. and Olokor, J.O. (2014). Monitoring the land-use and vegetation cover changes in the Kainji Lake Basin, Nigeria (1975-2006). *African Journal of Environmental Science and Technology*, 8(2): 129 - 142

Ipinmoroti, M.O. (2013). Ichthyofauna diversity of Lake Asejire Ecological Implications. *International Journal of Fisheries and Aquaculture*, 5: 248-252.

Kocher, T.D. (2004). Adaptive evolution and explosive speciation: the cichlid fish model. *Nature Reviews Genetics* 5, 288–298.

Meyer, C.P. and Paulay, G. (2005). DNA Barcoding: Error Rates Based on Comprehensive Sampling. *PLoS Biol.* 3(12): e422. https://doi.org/10.1371/journal.pbio.0030422

Morenikeji, O.A and Adepeju, A. I. (2009).

Helminth communities in Cichlids in natural and man-made ponds in south-west Nigeria. *Researcher*. 1(3):84-92

Nazeef, S. and Abubakar, U.M. (2013). Diversity and Condition Factor of Fish Species of Dadin Kowa Dam, Gombe State, Nigeria. *Greener Journal of Biological Sciences*, 3 (10): 350-356.

Nazeef, S., Ja'afar, A., Abubakar, K.A. and Kabiru, M. (2021). Fish species biodiversity of Dadin-Kowa reservoir: Current status. *World Journal of Advanced Research and Reviews*, 11(02), 100–111

Olaosebikan, B.D and Raji, A. (2013) Field guide to Nigerian Freshwater Fishes. Remi Thomas Press Nigeria. 144p

Olopade, O.A and Rufai, O.P. (2014). Composition, abundance and diversity of the Family Cichlidae in Oyan Dam, Ogun State, Nigeria. *BIODIVERSITAS*. 15 (2): 195 - 199. DOI: 10.13057/biodiv/d150211

Olufeagba, S.O., Aladele, S.E., Okomoda, V.T., Sifau, M.O., Ajayi, D.A., Oduoye, O.T., Bolatito, O.A., Nden, D.S, Fabunmi-Tolase, A.S. and Hassan, T. (2015). Morphological Variation of Cichlids From Kainji Lake, Nigeria. *International Journal of Aquaculture*, Vol. 5 (26): 1-10. DOI: 10.5376/ija.2015.05.0026

Salele, H. A.,, Bichi, A, H and Dauda, A. B. (2023). Species Composition, Size Distribution, Condition Factor and Growth Pattern of Cichlids from Zobe Reservoir, Dutsin-Ma, Katsina State, Nigeria. *FUDMA Journal of Agriculture and Agricultural Technology*, 9(2): 1-8

Sani B.M., 2Idowu R.T. and1Banyigyi, A. H.(2019) The Diversity of Fish Species, Composition and Abundance from Bodna River in Kwali Area Council, Abuja. *Nigerian Annals of Pure and Applied Science* 2: 41-48

Shannon, C.E. and Wiener, W. (1963). The Mathematical Theory of communication. U. illinois, Urbana,, illinois. 117 p.

Simpson, E.H. (1949). Measurement of Diversity. *Nature*: 163 - 688.

Sogbesan, O.A., Sanda, M.K., Ja'afar, J.N. and Adedeji, H.A. (2017). DNA Barcoding of Tilapia Species (Pisces: Cichlidae) from North-Eastern Nigeria. *Journal of Biotechnol Biomaterials*, 7: 277. doi: 10.4172/2155-952X.1000277

Trewavas, E. (1983). Tilapiine fishes of the genera Sarotherodon, Oreochromis and Danakilia. British museum (Natural History), London.

Upper Benue River Basin DevelopmentAuthority (1980). Feasibility Study of Lake Dadin Kowa Lake by Upper Benue River Basin development Authority. Authority Information Manual.

Upper Benue River Basin DevelopmentAuthority (1985). Feasibility Study of Lake Geriyo by Upper Benue River Basin development Authority. Authority Information Manual.

Van Dyke, F. (2003). Conservation Biology. Foundations, Concepts, Applications. McGraw-Hill Companies, New York.

Yem, I.Y., Bwala, R.L, Bankole, N.O., Olowosegun, M.O. and Yaji, A. (2011). Analysis of Ichthyofaunal Diversity and Peculiarities of Some Lakes in Nigeria. *Journal of fisheries International*, 6: 26-30.

Zira, J.D., Danba, E.P., Aliyu, B.A. and Enoch, B.B. (2017). Fish Species Diversity and Abundance of Kiri Reservoir, Shelleng Local Government Area, Adamawa State, Nigeria. *International Journal of Research in Agriculture and Forestry*, 4 (10); 24 – 3

CHROMOSOMAL ABERRATIONS INDUCED BY A COMBINATION OF INDUSTRIAL CHEMICALS IN AFRICAN CATFISH (*Clarias gariepinus*) AT LETHAL AND SUBLETHAL LEVELS

[*1]DAVIES, I. C., [1] E. S. ERONDU AND [2]E. G. AMAEWHULE
[1]Department of Fisheries, University of Port Harcourt, P.M.B. 5323, Port Harcourt, Nigeria.
[2] Department of Animal and Environmental Biology, Rivers State University, Port Harcourt, Rivers State, Nigeria.
*Corresponding Author: davies.chris@uniport.edu.ng, +234 703 882 5990

ABSTRACT
The aim is to assess the variation in the karyotype number of chromosomes in C. gariepinus and the genetic consequences of exposure to mixed industrial chemicals in the African Catfish, providing valuable information for environmental management, conservation, and potential human health considerations. From the acclimation tanks, ten healthy and active juveniles were randomly selected with five test concentrations: 0.0ml/l (control), 25ml/l, 50ml/l, 100ml/l, 150ml/l, 200ml/l, and 250ml/l for lethal, and 0.0ml/l (control), 12.8ml/l, 25.59ml/l, 38.39ml/l, 51.19ml/l, and 63.99ml/l. Chromosomal aberration studies were conducted on the fish samples after 4 and 28 days of exposure. The study examines the karyological and cellular content of Clarias gariepinus, revealing a consistent 2n = 56 karyotype across the fish. Variability in individual karyotypes suggests aneuploidy and genetic material loss during gametogenesis. In C. gariepinus exposed to lethal concentrations of mixed chemicals, significant karyotype variations have implications for genetic health and environmental impact. Changes in metacentric, submetacentric, subtelocentric, and acrocentric/telocentric chromosomes signal genetic instability, crucial for species integrity and resilience. Genetic alterations may adversely affect reproductive success, leading to abnormalities in gamete formation and reduced reproductive fitness. Sub-lethal exposure to the mixed induces alterations in the karyotype of C. gariepinus, despite a consistent diploid number of 56. As a result of exposure to the chemical (Xylene: Diesel), mutations may occur, potentially altering karyotype structure and disrupting division control. Sublethal and lethal concentrations cause genotoxic effects. Genetic diversity and health are affected by C. gariepinus populations. For long-term effects to be predicted, it is important to understand the consequences of karyotype changes in C. gariepinus to predict the genetic health of the population in the future.
Keywords: *Genetics, African Catfish, Karyotype, Chemicals, Environmental*

INTRODUCTION

Oil and gas exploration and production in Nigeria, a key economic sector, are not without environmental costs. Modern exploration techniques contribute significantly to pollution and adverse effects on aquatic life. The petroleum industry, particularly offshore oil exploration, poses a significant threat to the health of aquatic biota, particularly the African catfish (*Clarias gariepinus*), a vital fish species in Nigeria and a potential bio-indicator of aquatic ecosystem perturbations (Akinsanya *et al*., 2018; Osisiogu *et al*., 2019).

Toxic chemicals released during well stimulation and cleaning can modify water physicochemical parameters, potentially affecting fish and other aquatic organisms (Gunaalan *et al*., 2020; Aliko *et al*., 2022). This has raised global concerns about the impact of petroleum operations on the environment, particularly on species like the African catfish. According to Orowe and Ikponmwen, 2022), the vulnerability of the African catfish to modifications in the aquatic ecosystem, especially when exposed to chemicals from oil production, is a cause for concern.

As Nigeria grapples with the delicate balance between economic development and environmental sustainability, it becomes imperative to understand the intricate relationship between oilfield chemicals, genetic health, and ecological stability. The petroleum industry must be scrutinized for its environmental footprint. The decline in fish populations globally, attributed to anthropogenic and natural contaminant inputs, calls for comprehensive research on the impact of these contaminants on the genetic composition and health of aquatic organisms (Amoatey and Baawain, 2019; Ali *et al*., 2019).

The ongoing industrial activities, particularly in the oil and gas sector, have raised concerns about their potential environmental impact, specifically on aquatic ecosystems. The release of industrial chemicals, such as the water-soluble fraction (WSF) of xylene and diesel, into aquatic environments poses a threat to aquatic organisms (Davies, *et al*., 2019a). In this context, the African catfish (*Clarias gariepinus)* emerges as a crucial bio-indicator species, reflecting the ecological health of aquatic ecosystems.

This study endeavours to assess the genetic and chromosomal repercussions induced by the exposure of African catfish to the water-soluble fraction (WSF) of xylene and diesel, two prevalent industrial chemicals. The focus is on understanding the genotoxic effects that these chemicals may exert on the genetic and chromosomal integrity of the African catfish population. Through this assessment, the study also aims to evaluate chromosomal aberrations in African catfish, serving as a biomonitoring and ecotoxicology assessment in Nigeria, where petroleum exploration and production play a pivotal role in income and power. The outcomes have the potential to furnish valuable information for the efficient monitoring and management of aquatic ecosystems influenced by oil and gas exploration.

MATERIALS AND METHODS

Test Organisms {African catfish (*Clarias gariepinus*)}

A total of 420 healthy juvenile *C. gariepinus* juveniles, measuring 15.20±2.3cm and 10.23±2.60g respectively, were obtained from the University of Port Harcourt Demonstration Farm in Nigeria. due to their high sensitivity to environmental stress. Following previous studies (Davies et al., 2019b; Chris et al., 2022), juvenile developmental stages were selected as test organisms due to their heightened sensitivity to environmental stress.

Acclimation of the test organism

The fish were acclimated to laboratory conditions in a 150-litre glass aquarium tank for 14 days at 28±20C, fed commercial fish feed twice daily, and aerated continuously. Bennett and Dooley (1982) recommended replacing water in glass tanks with laboratory tap water every 48 hours.

Test Chemicals

The study used Water Soluble Fraction (WSF) of Diesel oil purchased from the Nigerian National Petroleum Corporation (NNPC) Filling station in Port Harcourt, Rivers State. Xylene was purchased from an oilfield chemical laboratory in Rivers State, Nigeria, and was stored in an ambient laboratory condition. A working stock solution was prepared from Xylene and Diesel following a standard method and a test chemical was prepared, using a volumetric and analytical method described in previous studies (Orlu and Ogbalu, 2013; Davies *et al*., 2019b).

Selection of Test Organism for the Assay

Ten healthy and active juveniles of uniform size were selected randomly from the acclimation tanks using a hand-held scoop net and transferred carefully into different treatment units for 28 days to test for the sub-lethal effect of the Xylene and Diesel (Sil *et al*., 2010). The experiment was carried out in triplicates including the control. The test was performed using a renewal method to maintain and level of dissolved oxygen minimizing changes due to metabolism by the fish during this experiment (Chris *et al*., 2022). Feeding was suspended 24 hours before the renewable exposure period which lasted for 28 days. Five test concentrations of 0.0ml/l(control), 12.8ml/l, 25.59ml/l, 38.39ml/l, 51.19ml/l, and 63.99ml/l were prepared, each test concentration was held in a plastic aquarium tank of 15 litres and filled to 10 mark. Ten fish were randomly selected and put in each of the test concentrations. Each treatment was replicated.

Selection of test organism for sub-lethal assay

Ten active and healthy fingerlings relatively of uniform size were picked randomly using a hand-held scoop net from the acclimation tanks and transferred carefully into the different treatment units for 96 hours and 28 days to test for the lethal and sub-lethal effects of the Xylene and Diesel (Sil *et al*., 2010). The treatments were in triplicates as well as the control. The test was performed using a static and renewal method and the exposure medium was renewed every week to maintain toxicant strength for the sub-lethal, level of dissolved oxygen, and minimize changes due to metabolism by the fish during this experiment (Chris *et al*., 2022). Feeding was suspended 24 hours before the renewable exposure period which lasted for 28 days. Five test concentrations of 0.0ml/l (control), 25ml/l, 50ml/l, 100ml/l, 150ml/l, 200ml/l, and 250ml/l for the lethal while 0.0ml/l (control), 12.8ml/l, 25.59ml/l, 38.39ml/l, 51.19ml/l, and 63.99ml/l for the sub-lethal were prepared, each test concentration was held in plastic aquarium tank of 15 litres and filled to 10 mark. Ten fish were randomly selected and put in each of the test concentrations. Each treatment was replicated. After 4 and 28 days of exposure, the fish samples were then taken to the Regional Center for Biotechnology and Bioresources Research laboratory at the University of Port Harcourt for Chromosomal aberration studies. Analyses

Preparation of Metaphysic Chromosomes Procedure

The test organism (*C. gariepinus*) was placed into a 250ml beaker containing 0.007% colchicine solution prepared in freshwater and allowed to swim for 4 hours. The sample of the gill was chopped into 2-3 mm small pieces using a clean razor blade and the pieces were exposed to a hypotonic solution of 0.4% KCl (20-30 minutes). The hypotonic solution was discarded and the tissues were fixed by washing the chopped pieces twice in a freshly made cold mixture of 3:1 ethanol: acetic acid for 30 minutes. The tissue was stored in a fixative (acetone) for several hours at 4ºC. The pieces were removed from the fixative and the excess fixative was dried on a paper towel. The pieces were then placed on a micro slide and 2-3 drops of 50% acetic acid were added. The pieces were chopped until a cell suspension was formed.

The micro slides were thoroughly cleared of any form of contaminants using a 1:1 ether: ethanol mixture and were warmed on a heat plate at 40-50ºC. The cell suspension was taken with a Pasteur pipette and allowed to fall from a distance of 12cm on a precleaned and prewarmed micro slide. This process was repeated several times forming 2-3 rings of cells 1cm in diameter, and then the chromosome preparation was allowed to dry for 10-15 minutes. Finally, the chromosomes were stained with 15% Giemsa for 10-15minutes. The slides were prepared using the standard protocol of Henegariu *et al*. (2001), air-dried, covered and viewed under a binocular LED Microscope (Model-215-RLED-ASC). Well-separated chromosome metaphases were observed in the periphery of the rings formed and were photographed.

A karyogram was prepared by high contrast chromosome photographs and the individual chromosomes were cut out of the photographs. Classification and karyotyping of the chromosomes were performed according to the techniques described by Levan *et al*. (1964) and Ergene *et al*. (1998). The final karyogram was then scanned and printed.

Statistical Method

The results were analyzed using a Microsoft Excel sheet (Microsoft Office suite (2022) for a graphical representation and the standard error.

Ethical Approval

Ethical approval was obtained from the Office of Research and Development (Research Ethics Committee) at the University of Port Harcourt after due deliberation and my research proposal was approved.

RESULTS

Karyotype change associated with the exposure of *C. gariepinus* to Lethal concentration of Combined Oilfield chemicals.

The results presented in Table 1 demonstrate the impact of lethal concentrations of the combined chemicals (Xylene and Diesel) exposure on the karyotype of *C. gariepinus*. The diploid number of chromosomes (2n=56) remained consistent across all fish samples exposed to different concentrations of the toxicants, indicating no significant variations in the overall chromosomal count. However, the study reveals significant variations ($P<0.05$) in the shape and number of karyotypes, specifically classified as metacentric (M), submetacentric (SM), subtelocentric (ST), and acrocentric/telocentric (A/T).

At 0 ml/l, the karyotype contains 12 metacentrics (M), 16 submetacentric (SM), 8 subtelocentric (ST), and 14 acrocentric/telocentric (A/T) chromosomes, maintaining the diploid number of 56. Although the diploid number (2n=56) remains unchanged, there are changes in the karyotype, with an increase in metacentric (M) and subtelocentric (ST) chromosomes and a decrease in submetacentric (SM) and acrocentric/telocentric (A/T) chromosomes. As with the 25 ml/l concentration, the diploid number remains constant at 56, but there are additional changes in karyotype, with the metacentric (M) and subtelocentric (ST) chromosomes increasing and the submetacentric (SM) and acrocentric/telocentric (A/T) chromosomes decreasing. A concentration of 100 ml/l results in a diploid number of 56, but a modification of the karyotype, including an increase in metacentric chromosomes (M) and a decrease in submetacentric, subtelocentric, and acrocentric/telocentric chromosomes (A/T). The concentrations of 150 and 200 ml/l exhibit consistent changes in the karyotype, with an increase in metacentric (M) and submetacentric (SM) chromosomes and a decrease in subtelocentric (ST) and acrocentric/telocentric (A/T) chromosomes, while maintaining the diploid number. The karyotype exhibits alterations with increased metacentric (M) chromosomes, decreased submetacentric (SM) and subtelocentric (ST) chromosomes, and maintenance of the diploid number at 56 (Fig. 1 to 4) while well-separated chromosome metaphases were observed in the periphery of the rings formed as photographed in at Fig. 5.

Table 1: The chromosomes of *C. gariepinus* arranged according to type after exposure to different lethal concentrations of Xylene: Diesel.

Concentration (ml/l)	Karyotype type				Diploid chromosome numbers
	M	SM	ST	A/T	
0	12	16	8	14	2n =56
25	20	16	8	12	2n =56
50	20	14	8	14	2n =56
100	22	16	8	10	2n =56
150	26	18	6	6	2n =56
200	28	18	6	6	2n =56
250	28	16	4	8	2n =56

*Metacentric (M), Submetacentric (SM), Subtelocentric (ST) and Acrocentric/Telocentric (A/T)

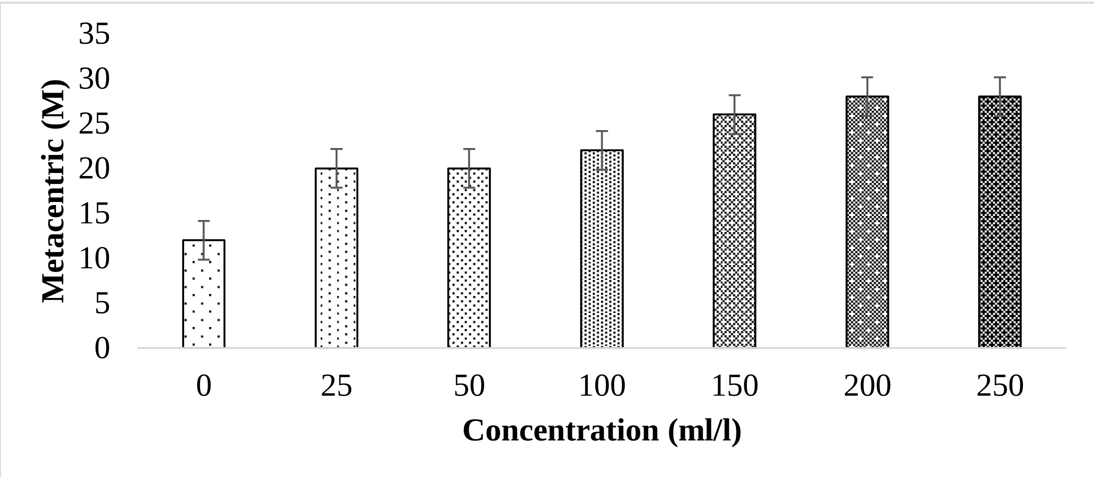

Fig. 1: Variations in metacentric (M) chromosomes after exposure lethal concentrations of the text chemicals.

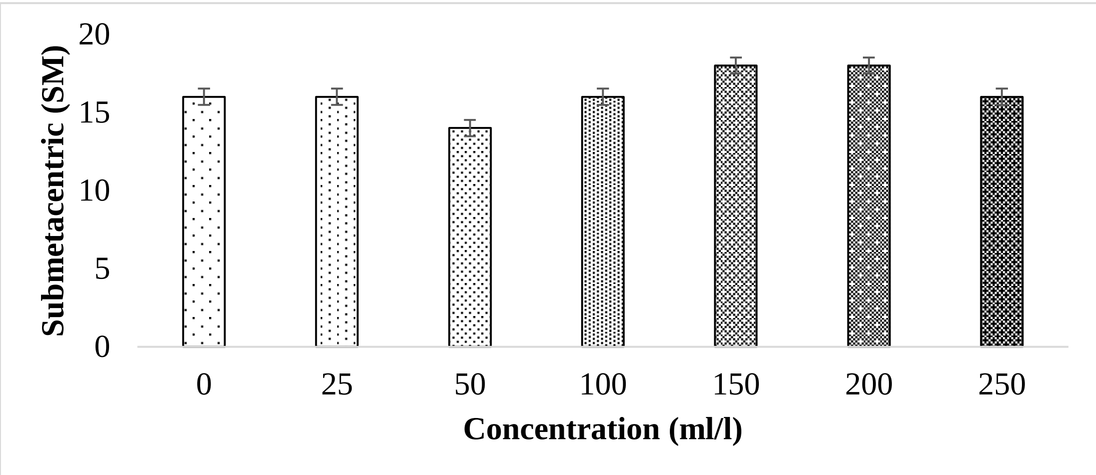

Fig. 2: Variations in Submetacentric (SM) chromosomes after exposure to lethal concentrations of the test chemicals.

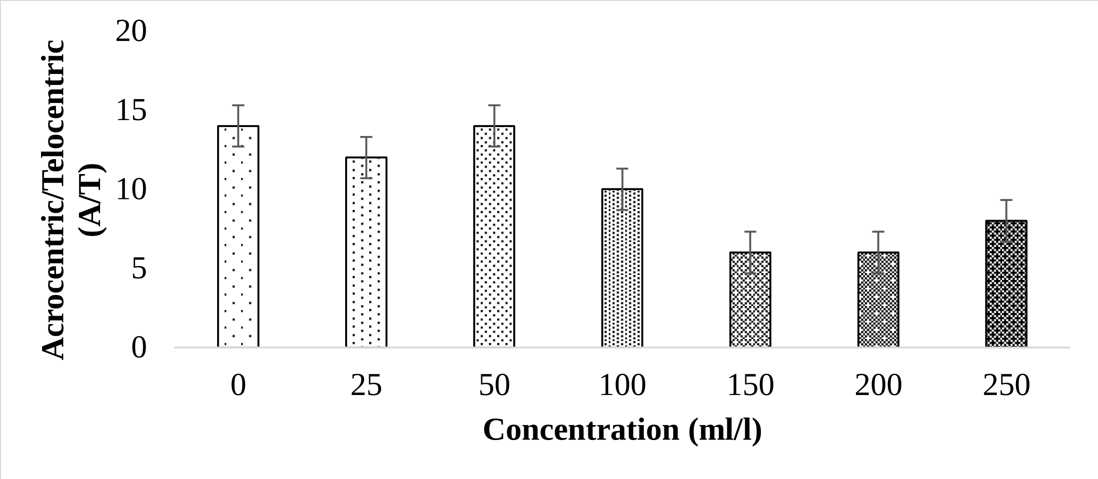

Fig. 3: Variations in Acrocentric/Telocentric (A/T) chromosomes after exposure to lethal concentrations of the test chemicals.

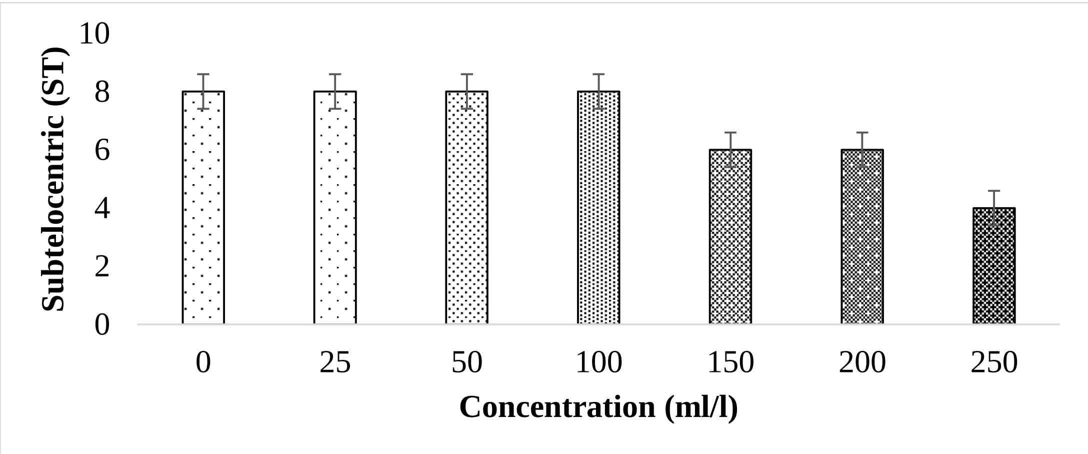

Fig. 4: Variations in Subtelocentric (ST) chromosomes after exposure to lethal concentrations of the test chemicals.

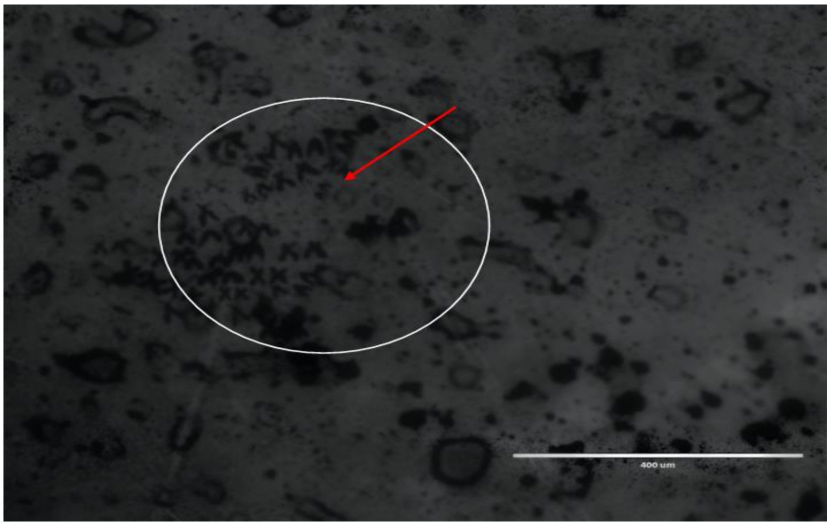

Fig. 5: Metaphase spread of the chromosomes at lethal exposure **(**100X Magnification).

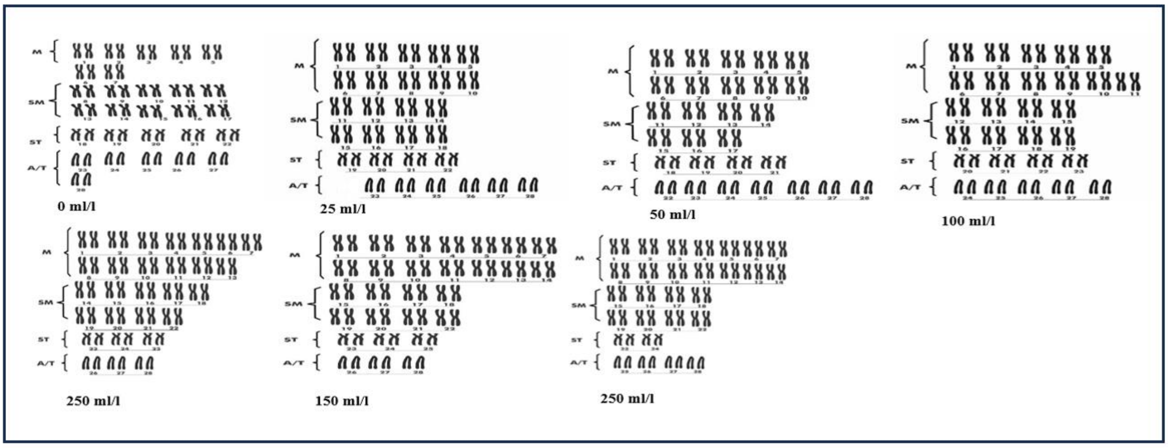

Fig. 6: The karyotype number of chromosomes and abnormalities of *C. gariepinus* exposed to a lethal concentration of Xylene: Diesel at the different levels of exposures (0 ml/l (Control), 25ml/l, 50ml/l, 100ml/l, 150ml/l, 200ml/l, 250ml/l) at 2n=56. Metacentric (M), Submetacentric (SM), Subtelocentric (ST) and Acrocentric/Telocentric (A/T).

Karyotype change associated with the exposure of *C. gariepinus* to Sublethal concentration of Xylene: Diesel

Table 2 shows the chromosomes' karyotype of *C. gariepinus* exposure to a sub-lethal concentration of Xylene: Diesel and most of the specimens showed well-spread chromosomes (Fig.s 4.45 to 4.50). At the end of the experiment, the diploid number of the test fish samples was the same (2n=56) for the different concentration groups, but for the different lethal levels of the toxicant, there was statistical significance in the number and shape of the karyotype such as metacentric, submetacentric, subtelocentric and acrocentric/telocentric of the fish samples (Fig. 6 to 10) while a well-separated chromosome metaphases were observed in the periphery of the rings formed as photographed in at Fig. 11.

Table 2: The karyotype of *C. gariepinus* arranged according to type after exposure to sub-lethal (SL) test concentrations of Xylene: Diesel

Sub-lethal concentration (ml/l)	Karyotype type				Diploid chromosome numbers
	M	SM	ST	A/T	
0	12	18	12	14	2n =56
12.80	12	18	10	16	2n =56
25.59	12	20	10	14	2n =56
38.39	10	24	8	14	2n =56
51.19	10	22	10	14	2n =56
63.99	8	18	10	20	2n =56

*Metacentric (M), Submetacentric (SM), Subtelocentric (ST) and acrocentric/telocentric (A/T)

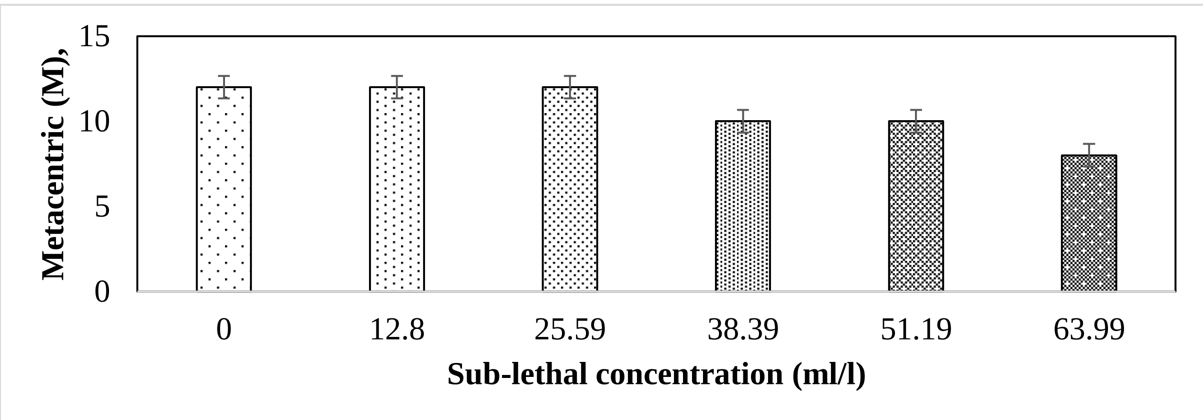

Fig. 7: Variations in metacentric (M) Chromosomes after exposure to Sub-lethal concentrations of the test chemicals.

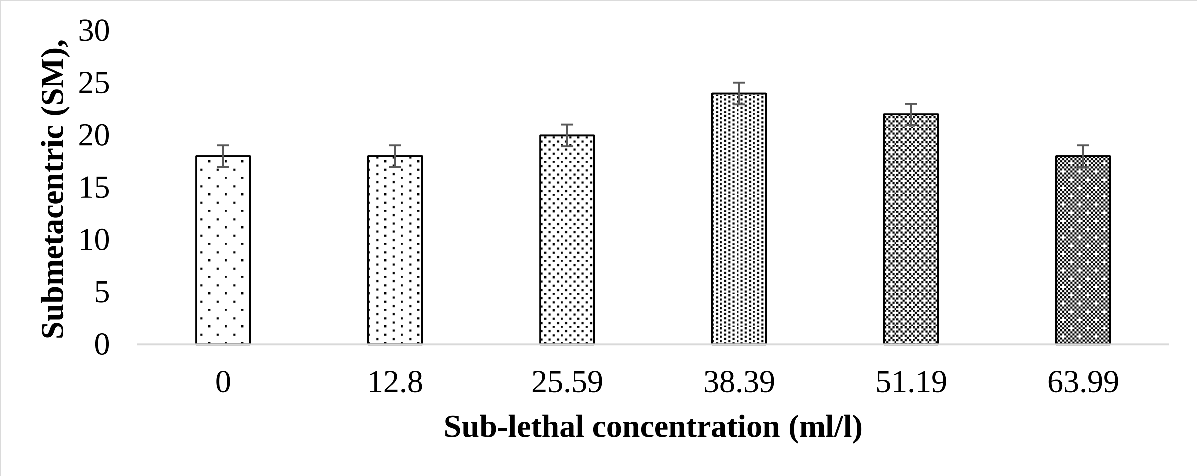

Fig. 8: Variations in Submetacentric (SM) Chromosomes after exposure to Sub-lethal concentrations of the test chemicals.

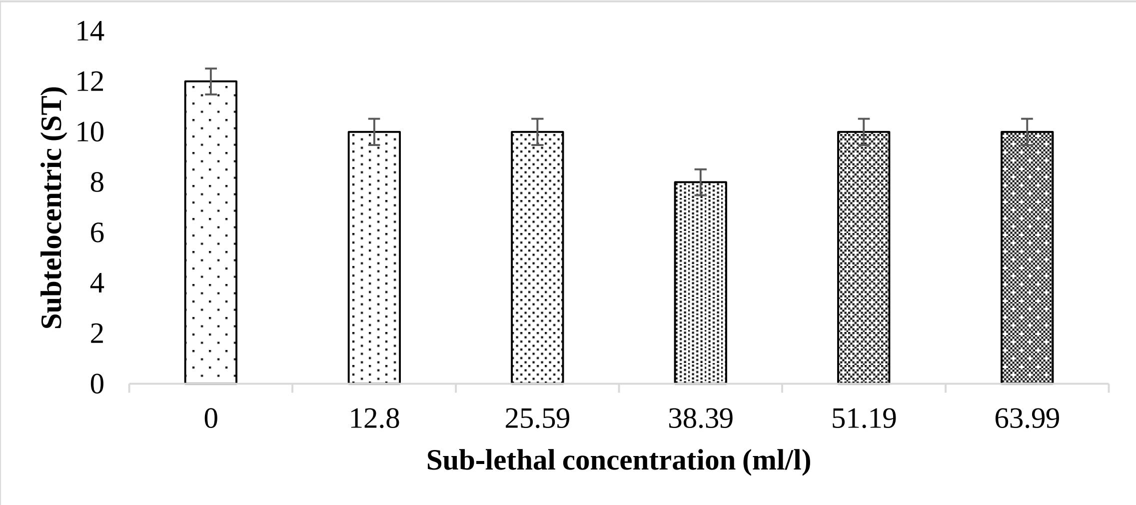

Fig. 9: Variations in Subtelocentric (ST) Chromosomes after exposure to Sub-lethal concentrations of the test chemicals.

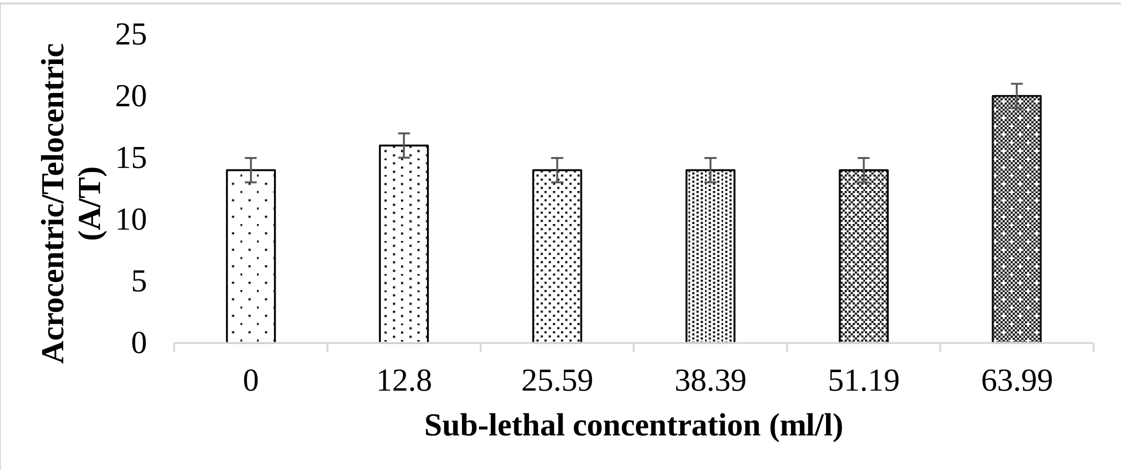

Fig. 10: Variations in Acrocentric/Telocentric (A/T) Chromosomes after exposure to Sub-lethal concentrations of the test chemicals.

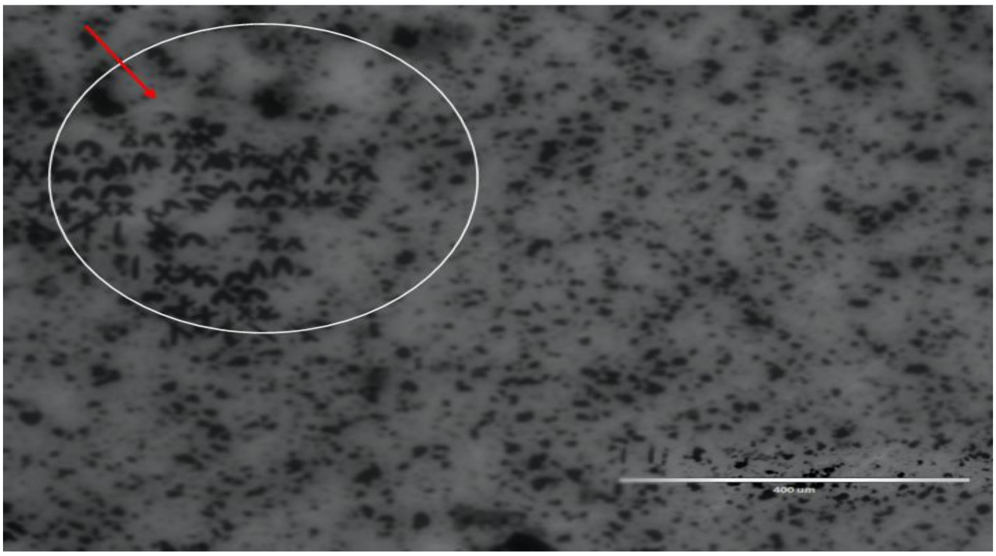

Fig. 11: Metaphase spread of the chromosomes at Sub-lethal exposure **(**100X Magnification).

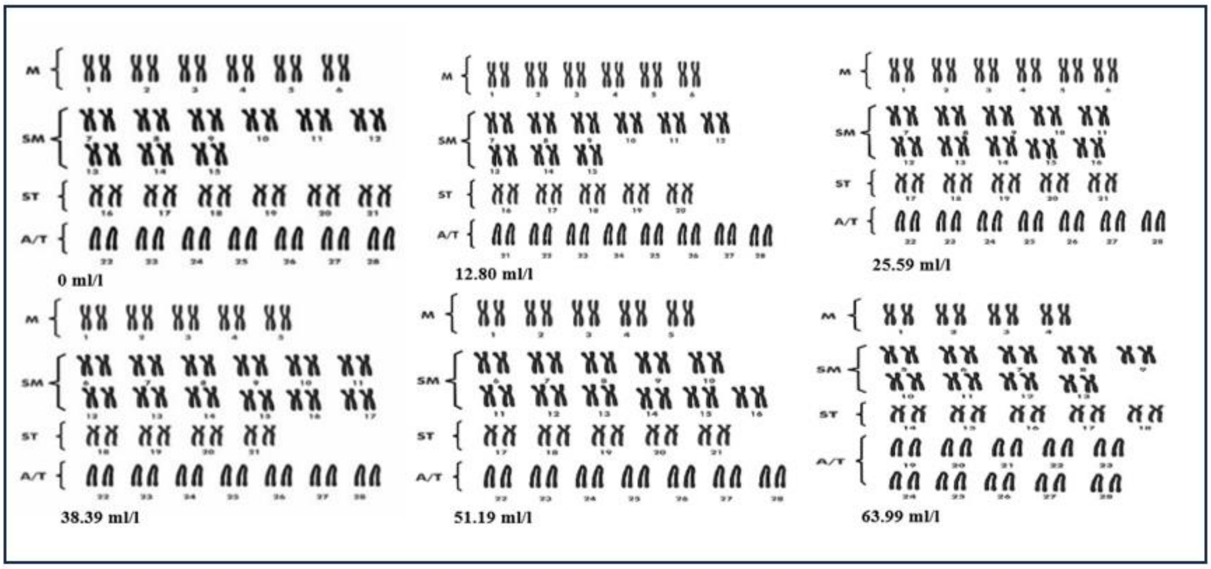

Fig. 12: The karyotype of *Clarias gariepinus* exposed to no toxicant (Control), 12.80ml/l, 25.59ml/l, 38.39ml/l, 51.19ml/l, 63.99ml/l at 2n=56. Metacentric (M), Submetacentric (SM), Subtelocentric (ST) and acrocentric/telocentric (A/T).

DISCUSSION

The study conducted karyological and cellular content studies to comprehend the systematics of fish species, revealing that all fish species exhibited karyotypes with a uniform 2n = 56, showcasing clear variability in the individual karyotype of the test fish. An observed imbalance of genetic material, referred to as aneuploidy, indicated a net loss or gain of genetic material during gametogenesis in the initial zygotic divisions, leading to variations in centromere positions and establishing strict borders between chromosomal categories. According to Kirsch-Volders *et al*. (2019), exposure to different chemical agents may induce mutations, potentially triggering the loss of division control and contributing to changes in the karyotype structure.

Lethal effect on *Clarias gariepinus*

The observed variations in the karyotype of *C. gariepinus* exposed to lethal concentrations of combined chemicals shows significant implications for genetic health and environmental impact. These alterations may potentially affect the genetic health and stability of the fish population. The changes in both the shape and number of karyotypes indicate genetic instability within the fish population, a critical factor for maintaining species integrity and resilience to environmental stressors (van Jaarsveld and Kops, 2016). Alterations in metacentric (M), submetacentric (SM), subtelocentric (ST), and acrocentric/telocentric (A/T) chromosomes suggest that exposure to toxicants may induce physical damage or rearrangements in the chromosomes of *C. gariepinus*. Such damage can impact the normal functioning of genes and genetic material, potentially leading to significant consequences for reproductive success (Han and Huang, 2021).

According to Tarín *et al*. (2000), changes in the karyotype may result in abnormalities during gamete formation, affecting fertilization and embryo development, and ultimately leading to reduced reproductive fitness. These observed karyotype variations serve as indicators of environmental stress, reflecting the impact of pollutants in aquatic ecosystems. Given the importance of *C. gariepinus* in maintaining ecological balance, genetic changes within this species may disrupt predator-prey relationships and biodiversity, compromising the general health of the ecosystem (Wangechi Kigano, 2016). The findings underscore the importance of conservation measures to mitigate the impact of anthropogenic activities, such as the release of oilfield chemicals, on aquatic life. Davies *et al*. (2019a), suggest that implementing measures to reduce toxicant exposure can contribute to preserving genetic diversity and overall ecosystem health.

Nevertheless, Hamilton *et al*. (2016) stated that consuming fish with genetic abnormalities or exposure to contaminants could pose risks to human health throughout the food chain. However, the observed variations in the karyotype of *C. gariepinus* highlight the intricate relationship between environmental stressors, genetic health, and ecosystem stability (Obiakor *et al*., 2014). These findings call for interdisciplinary research efforts, conservation initiatives, and environmental management practices to safeguard the genetic integrity of aquatic organisms and maintain the health of aquatic ecosystems.

Sublethal effect on *Clarias gariepinus*

The presented findings illustrate alterations in the karyotype of *C. gariepinus* following exposure to sub-lethal concentrations of Xylene: Diesel. A significant proportion of specimens exhibited well-spread chromosomes, indicative of successful karyotype analysis. The diploid number, consistently recorded at 56 across all test groups, suggests that the fundamental chromosomal structure of the test fish remained unaltered despite exposure (Glover *et al*., 2020). However, statistical analyses revealed noteworthy variations in both the number and configuration of karyotypes, encompassing metacentric (M), submetacentric (SM), sub-telocentric (ST), and acrocentric/telocentric (A/T) types.

Increasing concentrations of the chemical compounds corresponded to observable changes in the karyotype composition. There is a notable fluctuation in the number of metacentric, submetacentric, sub-telocentric, and acrocentric/telocentric chromosomes at different concentrations. However, the observed karyotype variations may imply potential genotoxic effects resulting from exposure to the test chemicals (Turkez *et al*., 2017; Bonciu *et al*., 2018). Such genotoxicity can lead to alterations in chromosomal structure and number, and the occurrence at sub-lethal concentrations suggests that even lower concentrations may exert sub-lethal effects on the genetic makeup of the fish (Žegura *et al*., 2011; Mahaye *et al*., 2017). These chromosomal changes are indicative of environmental stress and pollutant exposure, making karyotype monitoring a valuable tool for assessing the impact of contaminants on aquatic organisms (Daev and Dukelskaya, 2011). Despite the consistent diploid number, alterations in karyotype composition suggest potential risks to the health and genetic diversity of the *C. gariepinus* population.

According to Molina *et al*. (2014), metacentric chromosomes, characterized by a centrally located centromere, may signal structural changes to the fish's genome, while variations in submetacentric chromosomes could reflect genetic instability. Alterations in subtelocentric chromosomes may suggest potential chromosomal rearrangements and changes in acrocentric/telocentric chromosomes may indicate disruptions in chromosomal integrity (Simpson and Simpson, 2008). The findings highlight the significance of karyological content studies in explaining the systematics of fish species, as evidenced by the uniform 2n = 56 karyotypes in all fish species studied. The observed variability in individual karyotypes of the test fish suggests potential genetic alterations induced by exposure to lethal and sub-lethal concentrations of toxicants (Alimba and Bakare, 2016).

Aneuploidy, characterized by an imbalance of genetic material during gametogenesis, emerged as a notable outcome, signifying potential disruptions in chromosomal integrity (Pellestor and Gatinois, 2018). The changes in centromere positions further delineated strict borders between chromosomal categories, pointing towards the complexity of genetic alterations induced by toxicant exposure.

Kirsch-Volders *et al*., 2019) suggest that mutation occurrence due to exposure to different chemical agents is a critical factor influencing the karyotype changes. Throughout numerous divisions, accumulated mutations may lead to a loss of division control and contribute to variations in karyotype structure (Potapova and Gorbsky, 2017; Baudoin and Bloomfield, 2021). The potential damage to the genotype and phenotype of the organism, including translocations, inversions, deletions, and duplications, highlights the multifaceted impact of toxicants on genetic material (Beal *et al*., 2017). Accoding to Meistrich (2020), mutations in germ cells have significant implications, potentially causing abnormal development of embryos, prenatal death, or the birth of genetically defective offspring. The observed rearrangements in the karyotype indicate chromosomal aberrations that may contribute to the development of degenerative diseases and increase the frequency of mutations in germ cells, posing a serious threat to the reproduction of different species (Raudsepp and Chowdhary, 2016; Keller *et al*., 2018).

The study underscores the genotoxic effects of exposure to lethal and sub-lethal concentrations of toxicants, emphasizing the harmful nature of induced mutations. The observed variations in acrocentric and metacentric chromosomes further support the notion that the toxicants played a pivotal role in altering the chromosomes' karyotype.

CONCLUSION

The study has found that exposure to lethal and sub-lethal concentrations of Xylene: Diesel can cause significant variations in the karyotype of *C. gariepinus*, raising concerns about potential genotoxic effects and risks to the population's genetic health. These alterations highlight the complexity of genetic responses to environmental stressors and the need for further investigation to understand the underlying mechanisms and genetic implications of these chromosomal alterations. The study recommends further research into the specific genetic mechanisms responsible for these changes, incorporating advanced molecular and cytogenetic analyses. Long-term effects assessments should focus on understanding the consequences of karyotype changes in *C. gariepinus*, which are crucial for predicting the population's future genetic health. Future research should also explore the broader ecological implications of these alterations, focusing on the fish population's genetic diversity and resilience. Interdisciplinary collaboration is encouraged to facilitate a more comprehensive understanding of the observed genetic consequences.

REFERENCES

Aardema, M.J. and MacGregor, J.T. (2003). Toxicology and genetic toxicology in the new era of “toxicogenomics”: impact of “-omics” technologies. *Toxicogenomics*, 171-193.

Akinsanya, B., Adebusoye, S.A., Alinson, T. and Ukwa, U.D. (2018). Bioaccumulation of polycyclic aromatic hydrocarbons, histopathological alterations and parasito-fauna in bentho-pelagic host from Snake Island, Lagos, Nigeria. *The Journal of Basic and Applied Zoology*, 79(1), 1-18.

Ali, H., Khan, E. and Ilahi, I. (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation. *Journal of chemistry*, 2019.

Aliko, V., Multisanti, C.R., Turani, B. and Faggio, C. (2022). Get rid of marine pollution: bioremediation an innovative, attractive, and successful cleaning strategy. *Sustainability*, 14(18), 11784.

Alimba, C.G. and Bakare, A.A. (2016). In vivo micronucleus test in the assessment of cytogenotoxicity of landfill leachates in three animal models from various ecological habitats. *Ecotoxicology*, 25, 310-319.

Amoatey, P. and Baawain, M.S. (2019). Effects of pollution on freshwater aquatic organisms. *Water Environment Research*, *91*(10), 1272-1287.

Baudoin, N.C. and Bloomfield, M. (2021). Karyotype aberrations in action: the evolution of cancer genomes and the tumor microenvironment. *Genes*, 12(4), 558.

Beal, M.A., Yauk, C.L. and Marchetti, F. (2017). From sperm to offspring: Assessing the heritable genetic consequences of paternal smoking and potential public health impacts. *Mutation research/Reviews in mutation research*, 773, 26-50.

Bennett, R.O. and Dooley, J.K. (1982). Copper uptake by two sympatric species of Killifish Fundulus heteroclitus (L.) and F. majalis (Walbaum). *Journal of Fish Biology*, 21(4), 381-398.

Bonciu, E., Firbas, P., Fontanetti, C.S., Wusheng, J., Karaismailoğlu, M.C., Liu, D. and Papini, A. (2018). An evaluation for the standardization of the Allium cepa test as cytotoxicity and genotoxicity assay. *Caryologia*, 71(3), 191-209.

Chris, D.I., Samuel, E.E. and Sokiprim, A. (2022). Haematological and behavioural response of African catfish (*Clarias gariepinus*) (Burchell, 1822) exposed to sub-lethal concentration of xylene. *World Journal of Advanced Research and Reviews*, 14(1), 554-565.

Daev, E.V, and Dukelskaya, A.V. (2011). The Karyotype Instability of Wild Organisms Could Serve as a General Sign of Adverse Environmental Impact. *Journal of Environmental Indicators*, 6, 33-40.

Davies I.C., Ebere S.E., Aduabobo I. H. and Leo C. O. (2019a). Lethal Effects of Xylene and Diesel on African Catfish (*Clarias gariepinus*). *Journal of Environmental Science, Toxicology and Food Technology,* 13(5): 29-33. https://dx.doi.org/10.9790/2402-1305022933

Davies I.C., Ebere S.E., Aduabobo I. H. and Leo C. O. (2019b). Acute Toxicity of Xylene on the African Catfish *Clarias gariepinus. Journal of Applied Science and Environmental Management,* 23(7): 1251-1255. https://dx.doi.org/10.4314/jasem.v23i7.10

Glover, K.A., Harvey, A.C., Hansen, T.J., Fjelldal, P.G., Besnier, F.N., Bos, J.B. and Solberg, M.F. (2020). Chromosome aberrations in pressure-induced triploid Atlantic salmon. *BMC Genetics*, 21(1), 1-11.

Gunaalan, K., Fabbri, E. and Capolupo, M. (2020). The hidden threat of plastic leachates: A critical review on their impacts on aquatic organisms. *Water Research*, 184, 116170.

Hamilton, P.B., Cowx, I.G., Oleksiak, M.F., Griffiths, A.M., Grahn, M., Stevens, J.R. and Tyler, C.R. (2016). Population-level consequences for wild fish exposed to sublethal concentrations of chemicals–a critical review. *Fish and Fisheries*, 17(3), 545-566.

Han, X. and Huang, Q. (2021). Environmental pollutants exposure and male reproductive toxicity: The role of epigenetic modifications. *Toxicology*, 456, 152780.

Henegariu, O., Heerema, N.A., Lowe Wright, L., Bray-Ward, P., Ward, D.C. and Vance, G. H. (2001). Improvements in cytogenetic slide preparation: controlled chromosome spreading, chemical ageing and gradual denaturing. *Cytometry: The Journal of the International Society for Analytical Cytology*, 43(2), 101-109.

Keller, A., Dziedzicka, D., Zambelli, F., Markouli, C., Sermon, K., Spits, C. and Geens, M. (2018). Genetic and epigenetic factors which modulate differentiation propensity in human pluripotent stem cells. *Human Reproduction Update*, 24(2), 162-175.

Kirsch-Volders, M., Pacchierotti, F., Parry, E.M., Russo, A., Eichenlaub-Ritter, U. and Adler, I.D. (2019). Risks of aneuploidy induction from chemical exposure: twenty years of collaborative research in Europe from basic science to regulatory implications. *Mutation Research/Reviews in Mutation Research*, 779, 126-147.

Mahaye, N., Thwala, M., Cowan, D.A. and Musee, N. (2017). Genotoxicity of metal based engineered nanoparticles in aquatic organisms: A review. *Mutation Research/Reviews in Mutation Research*, 773, 134-160.

Meistrich, M.L. (2020). Risks of genetic damage in offspring conceived using spermatozoa produced during chemotherapy or radiotherapy. *Andrology*, 8(3), 545-558.

Molina, W.F., Martinez, P.A., Bertollo, L.A.C. and Bidau, C.J. (2014). Evidence for meiotic drive as an explanation for karyotype changes in fishes. *Marine Genomics*, 15, 29-34.

Obiakor, M.O., Okonkwo, J.C. and Ezeonyejiaku, C. D. (2014). Genotoxicity of freshwater ecosystem shows DNA damage in preponderant fish as validated by in vivo micronucleus induction in gill and kidney erythrocytes. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, 775, 20-30.

Orlu, E. E. and Ogbalu, O. K. (2013). Evaluation of the effect of water-soluble fraction (Wsf) of bonny light crude oil and sublethal concentrations of Lepidagathis alopecuroides (Vahl) on reproduction in *Clarias gariepinus* (Burchell 1822). *Journal of Animal and Veterinary Advances*, 5: 240-244.

Orowe, A.U. and Ikponmwen, E.G. (2022). Concentrations of polycyclic aromatic hydrocarbons (PAHs) in the African catfish (Clarias gariepinus) juveniles exposed to crude oil contaminated water. *Chemistry of the Total Environment*, 2(1), 10-16.

Osisiogu, C.P. and Aladesanmi, O.T. (2019). Cadmium-induced toxicity and antioxidant enzyme responses in tissues and organs of African catfish (Clarias gariepinus). *African Journal of Biochemistry Research*, 13(5), 63-72.

Pellestor, F. and Gatinois, V. (2018). Potential role of chromothripsis in the genesis of complex chromosomal rearrangements in human gametes and preimplantation embryo. *Chromothripsis: Methods and Protocols*, 35-41.

Potapova, T. and Gorbsky, G.J. (2017). The consequences of chromosome segregation errors in mitosis and meiosis. *Biology*, 6(1), 12.

Raudsepp, T. and Chowdhary, B.P. (2016). Chromosome aberrations and fertility disorders in domestic animals. *Annual Review of Animal Biosciences*, 4, 15-43.

Sil, A., Wakadikar, K., Kumar, S., Babu, S.S., Sivagami, S.P.M., Tandon, S. and Hettiaratchi, P. (2012). Toxicity characteristics of drilling mud and its effect on aquatic fish populations. *Journal of Hazardous, Toxic, and Radioactive Waste*, 16(1), 51-57.

Simpson, K. and Simpson, K. (2008). *The development of a novel and efficient HAC vector delivery system to human cells* (Doctoral dissertation, University of Oxford).

Tarín, J.J., Pérez-Albalá, S. and Cano, A. (2000). Consequences on offspring of abnormal function in ageing gametes. *Human Reproduction Update*, 6(6), 532-549.

Turkez, H., Arslan, M.E. and Ozdemir, O. (2017). Genotoxicity testing: progress and prospects for the next decade. *Expert opinion on drug metabolism & toxicology*, 13(10), 1089-1098.

van Jaarsveld, R.H. and Kops, G.J. (2016). Difference makers: chromosomal instability versus aneuploidy in cancer. *Trends in cancer*, 2(10), 561-571.

Wangechi Kigano, S. (2016). *Genetic diversity, population structure and morphological characterization of the silver cyprinid Rastrineobola argentea (Pellegrin) in Port Victoria, Mbita and Nyanza Gulf of Lake Victoria (Kenya)* (Doctoral dissertation, JKUAT).

Žegura, B., Štraser, A. and Filipič, M. (2011). Genotoxicity and potential carcinogenicity of cyanobacterial toxins–a review. *Mutation Research/Reviews in Mutation Research*, 727(1-2), 16-41.