

Physicochemical Parameters, Microbiological Water Quality and Fish Abundance in Flooded Areas of Lokoja, Nigeria

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Abstract

This study evaluated the physicochemical and microbial water quality as well as abundance of fish fauna in the flooded area of Lokoja Metropolis (Kogi State, Nigeria) resulting from the flooding of the River Niger and River Benue between September and October 2012 due to the release of water from Lagdo Dam in Cameroon and Kanji Dam in Nigeria. Physicochemical and microbiological water qualities were determined using standard methods by APHA. Results obtained revealed that water quality deteriorated and fluctuated significantly. Microbial analysis of water from flowing river as well as those from flood plain was moderate in total coliform (0.042×10^5 and 0.45×10^5 respectively), while in residential areas, total coliform levels were critical (3.4×10^5 and 6.8×10^5). The study which recorded 7,518 fishes belonging to 9 families and 13 species indicated relative diversity with the use of various abundance indices. However, Cichlidae dominated (97.79%) the families in the study while Gymnarchidae had the least (0.013%) abundance. Water quality deterioration and lower species diversity in the study area were largely due to the flood.

Introduction

During the wet season, runoff originating from intense rainfall usually causes flooding. Surface runoff is the water flow which occurs when soil is infiltrated to full capacity and excess water from rain flows over the land (Waziri et al. 2012). For instance, the total annual surface runoff on River Niger at Lokoja is estimated to be 165.80 billion m^3 annually (Goldface-Irokalibe 2008). Usually, excess rainfall and surface runoff cause an increase in water volume in dams, hence, release of the surplus water becomes inevitable. This situation was seen in Nigeria where Lagdo Dam in the Republic of Cameroon released the excess water received from the River Benue in 2012 following persistent intense rainfall which almost overflowed the dam. Therefore as a safety measure so as to avert imminent flooding, the Government of the Republic of Cameroon announced its intention to release the excess water from the dam which is located on the axis of River Benue. In addition, excess water from the Kanji Dam in Niger State was released within the country at the same time causing flooding of the rivers downstream. Flooding may have tremendous effect on the water quality of areas affected, as it moves organic and inorganic components in its path along the course of the flooded areas causing eutrophication of the water bodies which may differ greatly from point to point along the same course. However, the extent of these changes is not well known.

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With urbanisation and industrialisation near the river bank, physicochemical qualities as well as microbiological quality of water are likely to change over time and over a short period of flood due to contamination with domestic sewage as well as organic material from industries. Faecal indicator bacteria like total coliforms, faecal coliforms (thermotolerant coliforms), *Escherichia coli* and intestinal enterococci (faecal streptococci) excreted by humans and warm blooded animals are discharged from sewage treatment plants and survive for a certain time in the aquatic environment (Kavka and Poetsch 2002). Studies on water quality changes of river system due to flood are scarce, hence, the present study observed microbiological level and water quality fluctuation at different sites.

Flooding is a potentially important influence on fish assemblages as represented by the flood pulse concept (Junk et al.1989). However, flood effects vary with flood severity (Resh et al.1988). Therefore, understanding how catastrophic floods (i.e., those far outside the range of usual seasonal water level fluctuations and ordinary disturbances), influence fishes is a topic of considerable interest in fish research (Kano et al. 2011). Positive relationship has been reported between water level and fish catch by several authors. Catches in the Cross River were strongly related to the high water flood regime at the beginning of each season as reported by Moses (1987). Rogers et al. (2005) also reported that spotted sunfish abundance was positively related to river levels in Florida and that low river levels negatively influenced fish abundance and fish communities. There is also an inverse relationship between the amount of water remaining in the dry season and the catch the same year due to increased vulnerability of fish (Vidy 1983). Duration of flooding also affects fish growth hence a longer period of flood allows a longer growth period for fish, and therefore a higher subsequent yield (Baran et al. 2001). However, it is assumed that the composition and abundance of fish species will also respond to changes in water depth and water quality produced by the flood. Hence, the study also monitored the catch composition of fishes in relation to different location in the flooded Lokoja Metropolis.

Materials and Methods

Description of study area

This research was conducted at Lokoja, from the 11th of September to 2nd of October 2012. Lokoja is situated in Kogi State, Nigeria; its geographical coordinates being 7°48' 0" North, 6° 44' 0" East. Lokoja is also the capital of Kogi State with an area of 3,180km² and a population of 195,261 at the 2006 census, with most of the population living close to the river bank because of the surrounding mountains and rivers. Flooding in the past in this area have been limited to seasonal water level fluctuations as a result of heavy downfalls and it usually recedes within 24 h, however the flooding in many states in the north of Nigeria in the year 2012 has been described as the worst, at a level not seen in a hundred years (ICSMD 2012). Even though a similar situation occurred in 1998, when the river covered and threatened some of the buildings at the riverbank, the situation was however not as bad as that experienced in 2012 (The Sun 2012). The confluence of the river

Niger and Benue at Kogi made the effect of the recent flood more pronounced compared to other states. Its highways connecting Abuja, the Federal Capital Territory, the north and the south were submerged. Many villages and towns were cut off from each other. Canoes became the mode of transport, ferrying commuters from one side of the town to the other (The Guardian Nigeria 2012). Lokoja, seemed to be the worst hit town with a total flooded area of 435.51 km² reported as at 26th September 2012 (RADRSAT-2 2012) which increased to 820 km² on 29th September 2012 (Terra SAR-X 2012).

Sample collection and analysis

For the present study, fish samples were collected at three sites (Fig. 1): flood plains (muddy bank areas usually water logged during the peak of the raining season), residential areas affected by adjoining streams (areas flooded as a result of stream recession due to elevated river level) and residential areas affected as a result of river spill beyond the flooded plains. The flood plains before the incident of the flood were basically used for the cultivation of rice, maize and millet. Water samples were collected at these sites and at 25-m mark of the usual bank of the river hence there were three fish sampling sites and four water sampling sites in the present study. Fish samples were collected over 4 wk using gillnet (10-15 mm stretched mesh size) and traps. The traps were set as the flood water level rose and retrieved as the flood water receded. Most of the fish were caught by gillnet which was engaged twice weekly throughout the time of the field study (Table 1). Samples were identified with the aid of identification keys (Holden and Reed, 1972; Olaosebikan and Raji 1998; Idodo-Umeh 2003; Adesulu and Sydenham 2007). To assess fish biodiversity, several indices were used including the Shannon and Weaver diversity index (H) (Shannon and Weaver 1963); Simpson's Index (D) (Simpson 1949); Pielou's evenness index (J) (Pielou 1966) and Margalef's diversity Index (di) (Margalef 1968). All indices were determined using Gen Stat (VSNi 2008) discovery edition 4 software (Lawes Agricultural Trust Rothamsted). Water samples were taken twice during the study period (at the peak of the flood in the 2nd and 3rd week of the experiment) and analysed for physicochemical parameters (pH, dissolved oxygen (DO), conductivity, alkalinity, total suspended solid (TSS) and temperature) and biological water quality at Kofa Services laboratory Jos according to APHA (1998). Turbidity was read using a Secchi disc, and water depth at each sampling site was determined in triplicate trials at the peak of the flood. Means of water quality parameters of the various study areas were separated (ANOVA) using Gen Stat (VSNi 2008) while biological parameters were subjected to Kruskal-Wallis test.

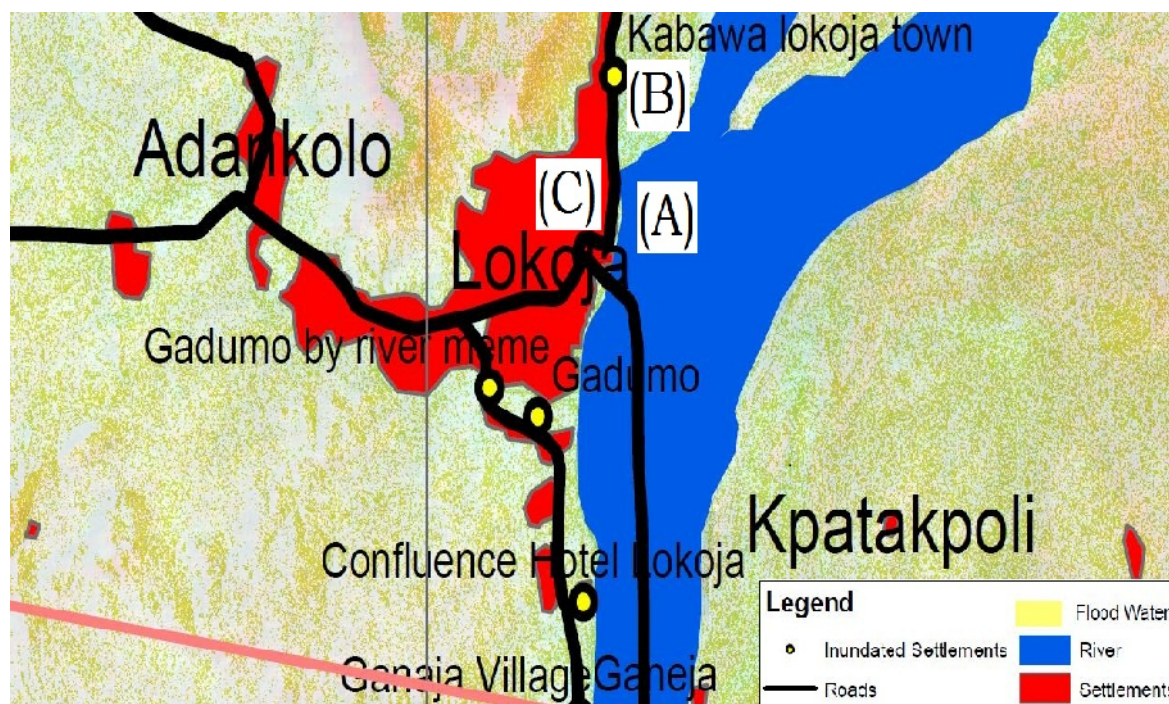


Fig. 1. Map showing study site (adapted from NASRDA 2012).

(A) Flood plains (muddy bank areas usually water logged during the peak of the raining season).

(B) Residential areas affected as a result of river flow beyond the flooded plains (RAARFP).

(C) Residential areas affected by adjoining streams (RAAAS) (areas flooded as a result of stream recession due to elevated river level).

Table 1. Species abundance of flooded areas of Lokoja Metropolis

Family	Species	Proportion	Gear efficiency (G %: T %)	Flood plains	R. A. A. by adjoining streams	R. A. A. as a result of river flow beyond the flooded plains
Clariidae	<i>Clarias gariepinus</i>	0.29	90.9 : 9.1	2	5	15
Mormyrydae	<i>Mormyrop deliciosus</i>	0.11	50 : 50	6	2	-
	<i>Mormyrus rume</i>	0.013	100 : 0	1	-	-
Gymnarchidae	<i>Gymnarchus niloticus</i>	0.013	100 : 0	1	-	-
Bagridae	<i>Bagrus bayad</i>	0.2	100 : 0	10	3	2
	<i>Clarotes macrocephalus</i>	0.12	100 : 0	5	4	-
	<i>Auchenoglanis biscutatus</i>	0.12	100 : 0	7	2	-
Malapteruridae	<i>Malapterurus electricus</i>	0.07	100 : 0	5	-	-
Mochokidae	<i>Synodontis budgetti</i>	0.05	100 : 0	2	2	-
Protopteridae	<i>Protopterus annectens</i>	0.86	0 : 100	39	22	4
Cichlidae	<i>Oreochromis niloticus</i>	66.32	61.87 : 38.13	1324	1008	2654
	<i>Tilapia zilli</i>	31.47	52.57 : 47.43	542	677	1147
Osteoglossidae	<i>Heterotis niloticus</i>	0.36	100 : 0	24	3	-
Total		100		1968	1728	3822

Key: R. A. A=Residential Areas Affected, G = Gill net, T = Traps.

Results

Fish abundance and diversity

A total of 7,518 fishes were recorded in the present study which included 9 families and 13 species (Table 1). Out of this number, 1,968 specimens were obtained from flood plains, 1,728 from areas affected by adjoining streams while 3,822 specimens were taken from residential areas affected as a result of river flow beyond the flooded plains. It was observed that of the two gears used, gill nets were more efficient in collection of most fish species compared to traps. However, it was not efficient for *Protopterus annectens* (Owen 1839). Cichlidae dominated (97.79%) the families of fish recorded during the study while Gymnarchidae was less abundant (0.013%). The fish population was relatively diverse (Table 2) with indices driven by the relative dominance of the members of the Cichlidae.

Table 2. Fish assemblage and diversity indices of flooded areas in Lokoja, Kogi state, Nigeria

Parameters	Total number sampled	Interpretation
No. of families	9	-
No. of genera	13	-
No. of species	13	-
Margalef's diversity index di	1.46	Relatively diverse
Shannon-Weiner, H	0.762	"
Simpson's index, D	0.461	"
Species evenness, J	0.297	"

Water quality

Significantly higher values for most physicochemical parameters (except for dissolved oxygen and pH) were observed in flooded residential areas compared to flooded plains and flowing river water (Table 3). Water depths in residential areas were shallow (3.9 and 2.7m) compared to the flood plains (5.7m) and the water depth in the river was the highest (12.1m). The water samples from the residential areas were also heavily loaded with total coliform (3.4×10^5 and 6.8×10^5 for RAAAS and RAARFP respectively) compared to other two sites (0.042×10^5 and 0.45×10^5 for flowing river and flood plain respectively).

Table 3. Physicochemical/biological water parameters in flooded areas of Lokoja Metropolis

Water quality parameters	Flowing river water	Flood plains water	Water from R. A. A. by adjoining streams	Water from R. A. A. as a result of river flow beyond the flooded plains	P-Value
Water Depth (m)	12.1 x 0.03 ^a	5.7 x 0.22 ^b	3.9 x 0.54 ^c	2.7 x 2.15 ^d	0.031
Turbidity (cm)	6.0x 1.21 ^c	6.5x 0.87 ^b	7.8x 1.18 ^a	8.1x 0.18 ^a	0.04
DO (mg l⁻¹)	4.5x 0.21 ^a	4.0x 0.43 ^{ab}	3.7x 0.09 ^b	3.1x 0.24 ^c	0.001
pH (25°C)	6.5x 0.12	6.6x 0.15	6.5x 1.90	6.2x 0.22	0.27
Conductivity(µs/cm)	113x 2.11 ^b	135x 3.12 ^b	234x 1.35 ^a	287x 1.67 ^a	0.01
Temperature (°C)	27x 1.0	27.5x 2.1	28x 1.1	29x 1.8	0.18
T.S.S.(ppm)	220x 3.4 ^b	222.5x 2.8 ^b	262.1x 1.6 ^a	256.9x 2.6 ^a	0.02
Alkalinity(mg/l CaCO₃)	111.2x 2.11 ^c	115.7x 1.23 ^b	119.9x 0.23 ^a	122.1x 1.34 ^a	0.05
Microbiological Analysis					
TotalColiforms	0.042x 0.12 ^d	0.45x 0.11 ^c	3.4x 1.20 ^b	6.8x 0.13 ^a	0.03
(MPN/ 100mL x10⁵)					
<i>Escherichia coli</i>	0.034x0.34 ^c	0.039x 0.45 ^c	0.41x 0.03 ^b	1.4x 0.86 ^a	0.002
(MPN/ 100mL x10⁴)					

Means in the same row with different superscripts differ significantly (P<0.05).

R.A.A. = Residential Areas Affected

Discussion

The present study observed a total of 7,518 fishes comprising 9 families and 13 species. The occurrence of the pelvic chromine cichlids in shallow, upstream waters has been attributed to a predator avoidance strategy, since their piscine predators rarely visit such areas (Nwadiaro 1984). This observation seems to be in agreement with the present study as families such as Mormyrydae, Gymnarchidae, Malapteruridae, Mochokidae and Osteoglossidae observed in the flooded plain and river course were absent in flooded residential areas. However, Udoidiong and King (2000) noted that the rarity of the Cichlidae was probably linked to competitive disadvantage due to coexistence with the large cichlid relatives. Hence reduced number of Cichlid species was recorded in the present study compared to those from other studies in streams. Mondal and Kaviraj (2009) reported 49 species belonging to 23 families dominated by Cyprinidae with 11 species in the study of the piscine assemblage of two floodplains lakes in the Bongaon subdivision of the North Parganas in West Bengal, India. The effect of flooding probably affected the fish fauna assemblage in the present study leading to reduced composition

compared to reports by Udoidiong and King (2000) and Mondal and Kaviraj (2009). In a study conducted by Matthews (1986), fish fauna were reported to be drastically affected over a short period after a severe flood event in Arkansas. Similarly, in Japan, the density of the population of the sculpin *Cottus pollux* (Gunther 1873) considerably decreased due to a heavy flood event and resulting environmental changes and habitat limitations (Natsumeda 2003). On the other hand, some surveys of flood events have reported limited or no impact on fish species or populations (Tew et al. 2002; Lojkásek et al. 2005; Pires et al. 2008). Nevertheless, the impact of a flood on fish assemblages is dependent on its magnitude. The higher number of *Clarias gariepinus* (Burchell 1822) recorded for residential areas was likely to be linked to affected household ponds, which predominantly rear this species. It is assumed that captive fishes will take time to adapt to changes in flowing characteristics such as depth, current and quality hence they are likely to stay close to shallow areas and therefore prone to capture. The occurrence of a larger number of *P. annectens* (39) in flooded plain compared to residential areas (22 and 4) might be due to better adaptation terrain provided there (Okafor et al. 2012). Even with a large sample size of 7,518 observed within 4 wk of the study, the value obtained for species evenness (0.297), Shannon-weiner (0.762) and Simpson (0.461) were very low (Table 2) compared to studies earlier conducted by Onuoha et al. (2010) and Imefon (2012) in tributaries of the same river before the flood. Diversity has been reported to be higher in older communities than newly established ones (Odum 1971). This postulate agrees with the low diversity in Udom stream as reported by Udoidiong (1988), where its headwater dried up sometimes and so the condition might have disrupted the community balance leading to a reduction in species richness and diversity. It is also largely acknowledged that data gathered by gill net sampling are biased and thus do not reflect the exact abundance of different species and age groups (Kurkilahti and Rask 1996; Finstad et al. 2000). However, other commonly used fish sampling techniques were not applicable in the present study because of the nature of the areas which were formally residential. Trawling and seining (using big commercial seines suitable for catching adults of the typical species) were not possible due to little space, shallowness and stony bottom. Therefore, gill net sampling using standardized mesh sizes is still the most widespread method (Thoresson 1996) in studies like this. Nevertheless, result obtained may infer non-suitability for capture of some species, especially *P. annectens*, which in the present study were caught by local traps, but was not caught by gill nets, due to the cylindrical morphology of the fish and absence of spine-like fins which makes it easier to capture with gill net. Hence the absence of some fish species in the present study compared to previous studies may be due to the selectivity of the gears used.

The quality of water is explained by its physicochemical and biological properties. Although no reference was available on previous water quality record of the study area, it is however believed that the incident of the flood has caused significant changes to the water quality. Hence, comparison of the current water quality parameters were made with reported water quality of other tropical rivers and lakes by Khana and Ejike 1984; Olaniran 2000; Kolo

1996. Water quality difference was strongly attributed to flooding of both residential areas and farm lands on flooded plains at the study area. The water temperature obtained for all the sampling sites ranged from 27 to 30 °C. These range values compared well with the values reported for other tropical waters (Ovie and Adeniji 1993) and were within the recommended range for aquatic life in the tropical environment like Nigeria. The highest values obtained in the residential areas affected as a result of river flow beyond the flooded plains could be attributed to the warming effect of the solar radiation as a result of lower depth of water. Lower oxygen levels were observed for site with shallow bottom and so in contrast with the hypothesis of Abowei, (2010), who reported super saturated condition for very shallow streams. However, the difference may be attributed to larger amount of refuse as well as domestic and industrial water stagnated at these sites during the time of study, hence, consuming available oxygen in water for biodegradation. Solis (1988) stated that dissolved oxygen affects the growth, survival, distribution, behaviour and physiology of aquatic organisms; hence the study observed that the cichlidae dominated low oxygen areas of the present study as they tolerate low oxygen environment. The water conductivity of the study sites was higher than the range reported by Abowei et al. (2010) for natural waters. Conductivity provides a good indication of the changes in water composition particularly its mineral concentration. Therefore, variations of dissolved solids as a result of differences in the level of mineralization of domestic and industrial waste or from flooding and run off from nearby vegetation may have led to higher values of nitrate and other nutrient (Abowei et al. 2010), thereby making conductivity to increase at the different points in the sampled areas. Furthermore, Kutty (1987) stated that the combined form of the element is continually changing due to the process of decomposition and synthesis between organically bound forms and oxidized inorganic forms and this may occur at different rates in the same water body. Hence conductivity was not the same for the different sites of the study. The Secchi disc value (8.1 and 6.0 cm) obtained in the present study were largely because of floodwater and surface runoff during the time of the study. Kolo (1996) stated that lower turbidity usually recorded during the dry seasons is due to the absence of floodwater, surface runoff and the settling effect of the suspended solids due to cessation of rainfall. However the values obtained were not within the acceptable range of 30 and 60 cm recommended by Ayodele and Ajani (1999) for fish production and also lower than those of most tropical rivers and lakes reported by Olaniran (2000) and Khana and Ejike (1984). The total suspended solids were higher but in line with 30 ppm recommended by FEPA (1991). This also conforms with the report of Boyd and Lichtkoppler (1979). The pH of the site tends towards acidity and was lower than the recommended 7-8.5 range recommended for ideal biological productivity by Abowei (2010). Hence only fish (Cichlidae) adapted to a wide range of pH dominated the very acidic region of the study site. The excess production of carbon dioxide from respiration, decomposition and oxidation of organic matter was likely cause of water acidity in the study area. Higher water alkalinity (HCO_3 and CO_3) values recorded from residential areas could have been due to

domestic activity effects on water. However, alkalinity recorded in the present study were within the acceptable range for fish and shrimp production as reported by McNeely et al. (1979).

Bacteriological analysis of potable water sample of Gurgaon showed no faecal bacteria as reported by Koul et al. (2012). However the same study reported total coliform bacteria range of 2–20· 100 mL⁻¹, and estimated to be 30.7% of the tap water samples. The differences of the present study with that of Koul et al. (2012) are obviously attributed to differences in water source. The result of the present study for bacteriological analysis from flooded plain and flowing river water are in the range of those reported by Kavka and Poetsch (2002). However, higher values were observed in residential areas as compared to those described by these authors. Using the class limit values for microbial pollutions of rivers according to Kohl (1975) and Kavka and Poetsch (2002) for assessing bacteriological standard parameters, water from flowing river as well as those from flooded plain were “moderate” in total coliform, while water from residential areas were “critical”. More so residential areas affected as a result of river flow beyond the flooded plains were observed to be critical in *Escherichia coli* while other sites were considered moderate. The higher values of contamination observed in the present study for residential area could be attributed to the continuous impact of human wastes within the vicinity. *Escherichia coli* and faecal coliforms indicate the potential presence of pathogenic bacteria, viruses and parasites (Kavka and Poetsch 2002). Hence, fish reared in these water conditions (in cage culture or direct usage of water for raising fish in inland pond without treatment) may develop diseases if exposed long enough.

Conclusion

The present study showed deterioration of River Niger at the Lokoja axis caused by floods between September and October 2012. Fish species abundance in the flooded areas was reduced during the flood compared to previous studies on Nigerian inland waters. Kano et al (2011) had demonstrated that recovery in fish species abundance as a result of flood is over a period of 5years; therefore, continuous monitoring of the fish fauna and physicochemical parameters of the River Niger within the next few years is recommended to observe the recovery process. Furthermore, parasitic infection as well as fish species composition by assumption will change due to flood effect; hence research should be done to provide information on the residual effect of the flooded river.

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