Zooplankton community structure and dynamics during the transition from dry to rainy season: A case study of Kufena Inselberg (Rock) Pool, Zaria, Nigeria

Tanko, D.,[1*] **Chia, M. A.**[2] and **Nuhu, G.**[3]
[1]Department of Biological Sciences, Federal University Lokoja, Kogi State, Nigeria
[2]Laboratório de Cianobactérias, Escola Superior de Agricultura Luiz de Queiroz, University of São Paulo, Piracicaba-SP, Brazil. CEP: 13418-900
[3]Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria
*Corresponding author: daudakurdan@gmail.com

Abstract

This study investigates the zooplankton community structure and dynamics of Kufena Rock Pool during the transition from dry season (March to April) to rainy season (May to June) in Zaria, Nigeria. Physicochemical parameters such as temperature, hydrogen ion concentration, electrical conductivity and total dissolved solids were determined in the field using Hanna instrument. Other parameters were determined in the laboratory using standard techniques. Zooplankton were collected using silk plankton net of 20 cm diameter and 65 µm mesh size with a plastic bottle of 60 ml capacity attached at the bottom. Canonical Correspondence Analysis was used to determine correlation between the physicochemical parameters and the zooplankton species abundance. The transition from dry to rainy season was marked by decreasing nutrient concentrations with nitrate nitrogen having the highest value 5.71mg/L in March and lowest value of 2.7mg/L in June and phosphate phosphorus decreasing from 2.5mg/L in April to 1.25mg/L in June. There was increase in ionic content of electrical conductivity (208µs/m in March to 284 µs/m in May), water hardness (57.16mg/Lin April to 101.54mg/L in June), alkalinity (56.33mg/L in March to 85.75mg/L in June) and total dissolved solids (108mg/L in March to 191.02mg/L in June). Zooplankton community structure showed that species diversity and abundance decreased during the transition from 24 in March to 16 in June. 30 species of zooplankton in 5 phyla were encountered with Rotifera having the highest species richness (9 species). Copepoda had the highest relative abundance of 25.4%. There was a significant association between physicochemical characteristics of water and the zooplankton species. This study revealed that the physicochemistry of the rock pool is not insulated from the environmental changes associated with the transition from the dry to the rainy season in Zaria, which leads to changes in zooplankton community structure.

Keywords: Zooplankton; dynamics; diversity; rock-pool; physicochemistry; Kufena.

Accepted: 14 September, 2016.

Introduction

In an aquatic ecosystem, interaction occurs between living and non-living components. Ecologically zooplankton are among the most important biotic components influencing all the functional aspects of an aquatic ecosystem such as food chains, food-webs, energy flow and cycling of matter (Park and Shin, 2007). They are largely consumed by fishes and other higher animals in food chain (Redmond, 2008). Zooplankton are considered as indicators of environmental health (Aniel *et al* 2014). This is because eutrophication influences the composition and productivity of zooplankton.

Occurrence, diversity and density of both flora and fauna of any aquatic habitat is determine by the physical and chemical conditions of the water body (Ayodele and Adeniyi, 2006) which may change with season of the year. Ovie (1997) and Okogwu and Ugwumba (2006) reported how environmental factors such as physical and chemical properties of aquatic ecosystem influence the well being of aquatic species. Just as any species can be limited within a geographical region, so is zooplankton.

However, species of zooplankton are not uniformly or randomly within a region of the aquatic habitat. Specific species of zooplankton are restricted by salinity and temperature gradients, while others can withstand wide temperature range and salinity gradient (Lalli and Parsons, 1993). Zooplankton patchiness can also be influenced by biological factors, as well as physical factors. Biological factors include breeding, predation, concentration of phytoplankton and vertical migration (Lalli and Parsons, 1993). The physical factors that influenced the distribution of zooplankton the most is the mixing of the water column that affect nutrient availability and in turn, phytoplankton production

(Lalli and Parsons, 1993). Mountain pools represent a very important habitat that has been less explored in tropical aquatic ecosystems even though they are ubiquitous. Mountain pool species are usually physiologically and behaviourally adapted to the harsh conditions common to this habitat, which aid the persistence of their population in individual pools.

Most studies have recognized seasonal changes in plankton composition of small water bodies (Chia *et al* 2011, 2012). In fact the extent of water permanence and the length of the dry phase are usually tied to the plankton composition of other aquatic ecosystems as water losses occur from evaporation and evapotranspiration. The timing of wet and dry periods are well understood and defined for most parts of the world, but irregularities come during the transition from one season to another. These changes that occur during the transition period from the dry season to rainy seasons in mountain pools have rarely been investigated. Usually, this period is accompanied by changes in physical and chemical conditions of the aquatic ecosystems which determine the plankton community structures in them. The success of colonization and recruitment is a direct function of the extent to which the organisms can withstand changes in water physicochemistry during the transition from one season to another. The amount and quality of food resources available to zooplankton is affected as phytoplankton composition vary during this important period. Zooplankton density has been reported to vary depending on the nutrient availability and water stability (Nlewadim and Adeyemo, 1998, Hassan *et al* 2010).

To the best of our knowledge, these important ecosystems have been poorly studied with respect to zooplankton community structure and dynamics. Most published works are on the communities of emergent substrate than there is on the inhabitants of pools. Some of the published works on inselbergs include those of Tanko *et al* (2013) and Esson, *et al* (2015) who provided checklists of woody vegetation of Dumbi and Kufena inselbergs in Zaria respectively. Tanko *et al* (2014) reported on avifauna and non-avian vertebrate community structure associated with inselbergs. Adebote *et al* (2008) on the other hand studied mosquitoes breeding in rock pools around Zaria metropolis. None of these studies made mention of zooplanktons associated with the rock pools, hence the need for this study cannot be over-emphasized.

Our interest in this study was to investigate variations in zooplankton composition and physico-chemical characteristics of mountain rock pool during the transition from the dry season to the rainy season. This is because this aspect of the zooplankton ecology of rock pools is yet to be exhaustively investigated.

Materials and methods

Study area

Kufena Hills is located in Zaria Local Government, Kaduna State, Nigeria. It has a rugged terrain with various landforms and has a height of about 825 m above sea level. The hills and its environs have diverse flora and fauna species. Farm lands can be seen at the foot of the rock with animals grazing on and below the hills. This cultural landscape has great historical importance to the people of Kufena and Zaria, being the area of early settlement as evidenced by the remains of city wall around the hill, as well as some settlement, which remain on the hill. Kufena Hills was declared a National Monument on 17th July 1956. It is one of the four national monuments declared in Kaduna State and is protected under Act of Parliament, Cap 242 of 2000 formerly (Decree 77 of 1979) of the Federal Republic of Nigeria which established the National Commission for Museums and Monuments. Kufena is composed of metamorphic rocks, which forms the base material at the core of the major continental masses of the earth. The pool is located at the top of the mountain (11^o 052 01.72 2 N, 07^o 392 14.692 2 E) with a depth of *ca*. 1 meter and circumference of 0.5 km. Figures 1 and II are the maps of Zaria Kaduna State showing the study-site.

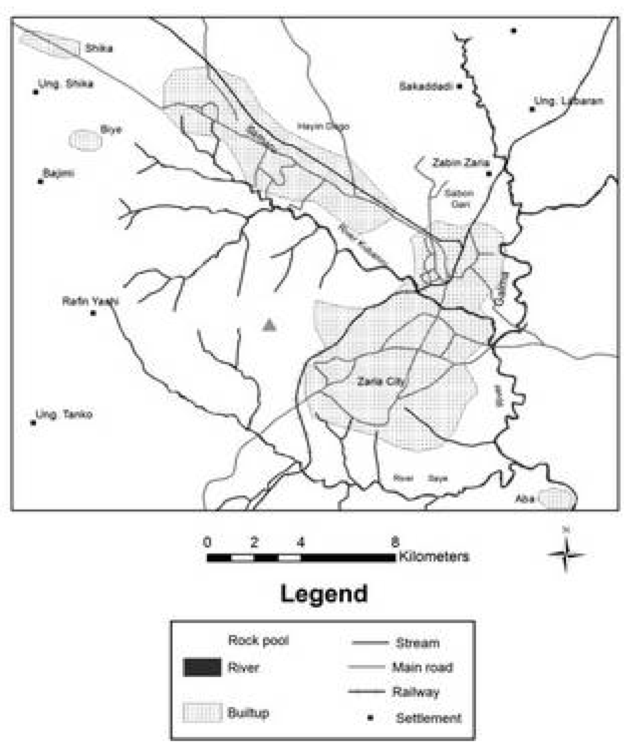

Figure 1. A map of Zaria, Kaduna State, with Kufena Pool which was the study-site.

Sampling

To effectively monitor changes in zooplankton composition over time, sampling was done twice a month for four months from March to June from fixed sampling stations. These months represent the end of the dry season (March and April) and beginning of the rainy eason (May and June).

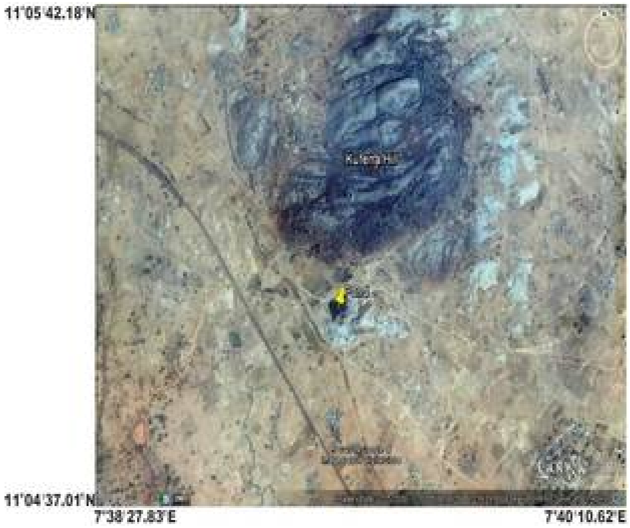

Figure 2. Google Earth of Kufena Hill with the pond.

Physicochemical parameters

Physicochemical parameters were determined from the pool between 8:00 am and 10:00 am. Hydrogen ion concentrations (pH), Electrical conductivity (EC), Total dissolved solids (TDS) and temperatures were determined at the sampling stations using HANNA (H1991300) instrument. Alkalinity and water hardness were determined following the procedures described in Lind (1979) and APHA (1998). Dissolved oxygen (DO) was determined using the modified Winkler azide method (Lind, 1979 and Sutherland, 1998). Nitrate-Nitrogen (NO_3-N) was determined using the Phenol Disulphonic acid method, as described by Mackreth (1963). The Denige's method (APHA, 1998) was used for the determination of phosphate-phosphorus (PO_4-P).

Zooplankton analyses

Zooplankton samples were collected using silk plankton net of 20 cm diameter and 65 µm mesh size with a plastic bottle of 60 ml capacity attached at the bottom. The net was towed through a distance of 5 m in the water and collected plankton samples were turned into other 100 ml plastic bottles and fixed with 5 ml of 4% formalin solution. Two replicate quantitative samples were taken and integrated to get one composite sample of 100 ml after concentrating by decantation. Identification of zooplankton was done using relevant identification resources such as Perry (2003), Lynne (2004) and Jeje and Fernando1986. Drop count method was used for enumeration as described by Chia *et al* (2011, 2012).

Number of organisms per litre = Number of organisms per ml of concentrate X V.
Where $V = \pi r^2 d$
Note: r = plankton net neck radius in cm,
d = length of the plankton net in cm.

Data analysis

Community structure analyses were done for each sampling month for the different zooplankton groups recorded. These comprised Shannon Diversity Index *H*, species evenness, dominance and Menhinick indices. The relationship between the physicochemical parameters and zooplankton species composition and abundance was determined using canonical correspondence analysis (CCA). The significance of the CCA was determined using the Monte Carlo permutation test with 1000 permutations. A *t*-test was used to compare the physicochemical parameter of the end of dry season months with the beginning of rainy season months. All analyses were done at 5% significance level. Community structure analyses, CCA were done using PAST software for windows version 2.09 (Hammer and Harper, Natural History Museum, Oslo, Norway).

Results

Physicochemical parameters of Kufena Rock Pool

This study investigates changes in physicochemistry of Kufena Rock Pool during the transition from the dry to rainy season in Zaria, Nigeria. The results showed that mean temperature values ranged from 20.80°C to 28.00°C from March to June (Table 1), and pH values from March to April were within the neural range (7.11-7.25). However, with the transition from the dry to rainy season the rock pool became alkaline (8.21-8.64). Electrical conductivity and TDS had a similar trend with the lowest values in the peak of the dry months, but with the transition to the rainy months their values were seen to have increased, though the increase was statistically non-significant ($p>0.05$). Alkalinity and water hardness values increased from March to June, with June having the highest values. Dissolved oxygen, nitrate nitrogen and phosphate phosphorus concentrations decreased from March to June (Table 1), however, it was only changes in phosphate phosphorus that differed significantly ($p<0.05$).

Zooplankton community structure and diversity

Thirty zooplankton species from five phyla; namely: Rotifera (9 species), Cladocera (8 species), Copepoda (5 species), Protozoa (4 species) and Annelid (4 species) were recorded (Table 2). Rotifera and Cladocera had the same relative abundances of 21.1%, Copepoda had the highest relative abundance of 25.4%, Annelida, 16.9% and Protozoa, 11.3%, had the least. Zooplankton community structure showed that the highest values were recorded in the dry month of March leading to the rainy months, however there was a slight decrease in April that was maintained in May, and then a slight decline in June (Table 3). Species dominance and Menhinik indices decreased from the March to April and then increased from May to June, showing the effect of the transition from the dry to rainy season. Species evenness increased from March to June, with June having the highest value

Table 1. Monthly variation in physicochemical parameters values of Kufena Rock Pool.

Physicochemical Parameters	March	April	May	June
Temperature (^oC)	20.80	27.70	27.65	28.00
Hydrogen ion concentration pH	7.25	7.11	8.64	8.21
Electrical Conductivity (µs/m)	208.00	228.00	284.00	282.00
Total Dissolved Solids (mg/L)	104.08	114.22	142.11	191.02
Alkalinity (mg/L)	56.33	66.11	81.67	85.75
Hardness (mg/L)	68.07	57.16	97.12	101.54
Dissolved Oxygen (mg/L)	9.08	7.73	7.31	5.05
Nitrate-Nitrogen (mg/L)	5.71	4.21	3.01	2.70
Phosphate-Phosphorus (mg/L)	2.40	2.50	1.25	1.25

Table 2. Zooplankton composition and distribution of Kufena Rock Pool Zaria, Nigeria.

Rotifera	Taxa abbreviation	March	April	May	June
Brachionus urceus	Brur	+	+	+	–
Brachionus capsuliflorus	Brca	+	+	–	–
Brachionus leydigii	Brle	–	+	+	+
Polyarthra vulgaris	Povu	+	–	–	+
Keratella quadrata	Kequ	+	–	–	–
Kellicottia longispina	Kelo	–	–	+	+
Asplanchna priodonta	Aspr	+	+	+	–
Filinia longiseta	Filo	+	–	–	+
Philodina roseola	Phro	+	–	–	–
COPEPODA					
Diaptomus gracilis	Digr	+	–	+	+
Cyclops strenuous	Cyst	+	+	+	+
Diacyclops longuidoides	Dilo	+	+	+	+
Nauplius larvae	Nala	+	+	+	+
Diaptomus stagnalis	Dist	+	–	+	–
CLADOCERA					
Daphnia pulex	Dapu	+	–	+	–
Daphnia laevis	Dala	+	+	+	–
Daphnia rosea	Daro	–	+	–	+
Simocephalus expinosus	Siex	+	–	–	–
Bosmina longirostris	Bolo	–	+	–	–
Diaphanosoma australis	Diau	–	+	–	+
Leptodora kindtii	Leki	+	–	+	–
Sida crystalline	Sicr	+	+	+	+
PROTOZOA					
Arcella mitrata	Armi	+	+	+	+
Dileptus binucleatus	Dibi	+	–	+	–
Urotachia saprophila	Ursa	+	+	–	–
Lionotus fasciola	Lifa	+	+	–	+
ANNELIDA					
Glycera savigny	Glsa	+	+	+	+
Glycera alba	Glal	+	+	+	+
Placobdella hollensis	Plho	+	–	+	–
Placobdella bistriata	Plbi	–	+	–	+

(1.00) recorded. Shannon increased from March to May, but drastically dropped to 2.773 in June. Zooplankton abundance and the number of taxa recorded decreased from March to June.

Zooplankton composition was observed to show significant association with the physicochemical characteristics of the pool (Figure 3). The most significant association between physicochemical parameters was observed for water hardness, electrical conductivity, alkalinity and temperature. These parameters were positively correlated with *Brachionus urceus, Cyclops strenuous, Daphnia laevis, Brachionus leydigii* and *Arcella mitrata.* However, *Simocephalus expinosus, Brachionus capsuliflorus, Filinia longiseta,* *Philodina roseola* and *Keratella quadrata* were negatively correlated with water hardness, alkalinity, and temperature. In sum, over 70% of the total variation was accounted for by the first two principal components of the CCA.

Table 3. Plankton community structure indices across the study period.

	March	April	May	June
Taxa_S	24.000	18.000	18.000	16;000
Individuals	40.000	24.000	23.000	16.000
Dominance_D	0.063	0.051	0.062	0.063
Shannon_H	2.831	3.074	2.834	2.773
Evenness_e^H/S	0.901	0.943	0.945	1.000
Menhinick	3.795	3.674	3.753	4.000

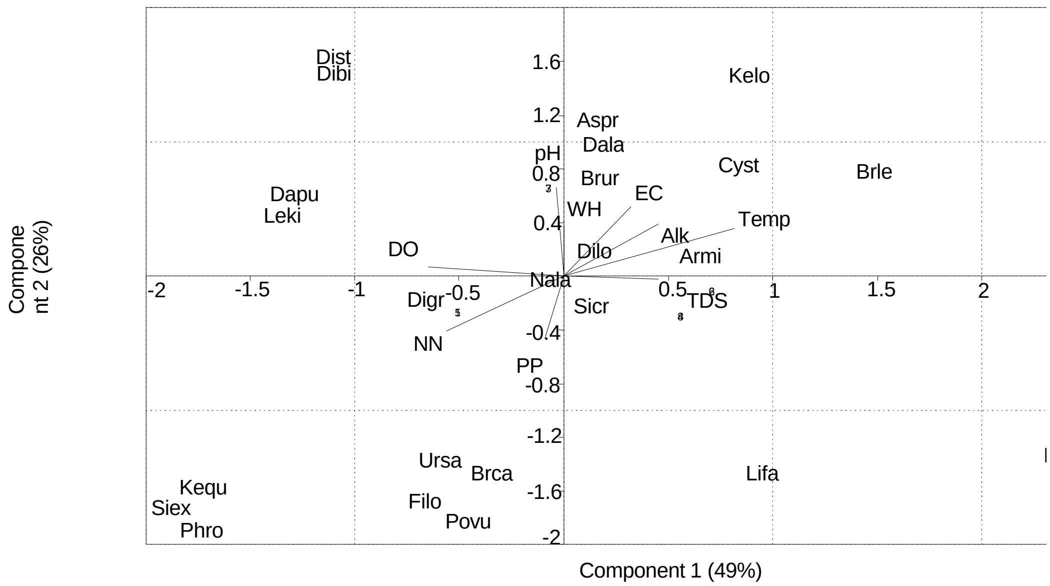

Figure 3. Association between the physicochemical characteristics of the water and the zooplankton species.

Discussion

The physicochemical characteristics of the pool show general trends that have been reported for other temporary small water bodies in Zaria, northern Nigeria, (Chia *et al* 2009, 2011, 2012). These studies show that the lower temperatures recorded in the dry months are as a result of the harmattan period, which is characterized by dry and cold winds. The higher electrical conductivity values recorded in the rainy season than in dry season is an indication of presence of more ions in the surface runoff, which could be due to influx of rock deposits and inorganic materials from the surroundings of the pool. The higher values of alkalinity recorded in the rainy season than dry season could be related to the high concentration of bases in this pool. This might also be as a consequence of the rock quarrying activities going on around the pool that provide the rock materials that are washed into the pool after every rainfall. The higher dissolved oxygen values in the dry-season could be connected to the fact that the rock-pool had higher primary productivity (higher zooplankton density and diversity) than the rainy-season (Chindah and Braide, 2004; Chia *et al* 2012). The higher phosphate-phosphorus and nitrate-nitrogen levels in dry season implicate a nutrient concentration mechanism that occurs due to the water levels reduction from the process of evaporation, thus without dilution from rain water, the nutrient levels as well as those of other chemical species are more likely to increase. Another possible contributor to the nitrate nitrogen and phosphate phosphorus levels could be related to the animals that drink from this pool and defecate into the water-body, as the pool is the major source of water for cattle, especially during the dry-season. Okogwu and Ugwumba (2006) reported that plankton maxima may occur at any time of the year in the tropics, depending on the conditions of the ecosystem. The progressive decline in zooplankton composition and abundance from March to June could be due to progressive change in the environmental conditions, the period of study being a transition from dry to wet season.

Changes in zooplankton population in Kufena Rock Pool could be attributed to different species having their nourishment at different temperatures, pH, alkalinity and nutrient condition (Chia *et al* 2011, 2012). High level of nutrients like N and P usually will favour the growth of chlorophyta and bacillariophyta which form the major diet of the zooplankton (Chia *et al* 2013). The variations of these nutrients have been reported by Chia *et al* (2013) to affect the food value of microalgae which in turn affect the zooplankton. This observation is in agreement with the report of Ezra and Nwankwo (2001) that plankton abundance and distribution are affected by seasonal variation of some physicochemical parameters as well as microplant life in aquatic ecosystems.

Zooplankton distribution and abundance at Kufena Rock Pool was found to show a close relationship with the physicochemical characteristics of the pool. Environmental factors, mainly water ionic content, water pH and temperature can explain the distribution and abundance of several zooplankton species. For example, water pH is known to affect crustacean plankton community structure and abundance, with crustaceans being less tolerable to pH variations (Obertegger and Manca, 2011). This may have been possible because the change in pH conditions did not go to the extremes of the pH scale. Our results show that the zooplankton community of Kufena Rock Pool do not show resilience to changing environmental conditions during the transition from the dry to rainy season due to the significant drop (>50%) in the number of taxa as well as abundance of the different taxa from March to June. According to Obertegger and Manca (2011), even when zooplankton species show resilience to changing local hydrological and hydrochemical conditions, it does not necessarily lead to the successful establishment of new species and/or maintaining populations of existing ones, even within a spatial range (<10 km) not considered limiting for passively transported zooplankton propagules. This means that seasonal variations in local conditions have a direct effect on the environmental characteristics of temporary aquatic ecosystems, which in turn determine the abundance and diversity of zooplankton.

In conclusion, the changing conditions within Kufena Rock Pool from the peak of the dry season to the beginning of rainy season had significant effects on the zooplankton composition and abundance of the water body. This was demonstrated by reduced species richness and diversity for zooplankton with reducing concentrations of important nutrients like nitrate nitrogen and phosphate phosphorus. This study reveals that the chemical and physical conditions of the rock-pool are not constant during transition, which leads to several associated changes in the zooplankton community structure and dynamics.

References

Adebote, D. A., Oniye, S. J. and Muhammed Y. A. 2008. Studies on Mosquitoes Breeding in Rock Pools on Inselbergs around Zaria, Northern Nigeria. *Jour. of Vect. Bor. Dis. 45:* 21-28.

American Public Health Association. 1998. *Standard Methods for the Analysis of Water and Wastewater.* American Public Health Association, New York, 1289pp.

Aniel, K. T., Girish, C. and Seema, K. 2014. Zooplankton Diversity in Shallow Lake of Su'Itanpur National Park Gurgaon (Haryana). Int. Jour. of Appl. Boil. and Parm. Tech. *5(1):* 35-40.

Ayodele, H. A. and Adeniyi, I. F. 2006. The Zooplankton Fauna of Six impoundments on the River Osun, southern Nigeria. *The Zoologist, 4:* 49-67.

Chia, A. M., Abolude, D. S., Ladan, Z., Akanbi, O. and Kalaboms, A. 2009. The presence of microcystins in aquatic ecosystems in northern Nigeria: Zaria as a case study. *Res. Jour. of Env. Toxicol., 3:* 170-178.

Chia, A. M., Bako, S. P., Alonge, S. and Adamu, A. K. 2011. Green algal interactions with physicochemical parameters of some man-made ponds in Zaria, northern Nigeria. *Braz. Jour. of Bot., 34(3):* 285-295.

Chia, A. M., Adelanwa M. A., Ladan Z., Iortsuun D. N., Adanyi, S. E., and Stephen, B. J. 2012. Interactions of *Ipomoea aquatica* and *Utricularia reflexa* with phytoplankton densities in a small water body in northern Nigeria. *Oceanol. and Hydrobiol. Stud., 41(2):* 39-47.

Chia, A. M., Lombardi, A. T., Melao, M. G. G. 2013. Growth and Biochemical Composition of *Chlorella vulgaris* in Different Growth Media. *Anais da Academia Brasileira de Ciencias 85:* 1427-1438.

Chindah, A. C., and Braide, S. A. 2004. the physicochemical quality and phytoplankton community of tropical waters: A case of 4 biotopes in the Lower Bonny River, Niger Delta, Nigeria. *Caderno de pesquisa serie Biologia, 16 (2):* 7-35.

Esson, A. E. Tanko, D., Adebola, M. I., Shuaibu, B. U. and Musa, D. D. 2015. Density and diversity of woody plants on Kufena Inselberg, Zaria Nigeria. *Afr. Jour. of Geo-Sci. Res., 3(3):* 08-11.

Ezra, A. G. and Nwankwo, O. I. 2001. Composition of Phytoplankton Algae in Gumbi Reservoir, Bauchi, Nigeria. *Jour. of Aqua. Sci., 16(2):* 115-118.

Hassan K. Y., Katama, A. S. and Ibrahim, Y. 2010. Algal diversity in relation to physicochemical parameters of three ponds in Kano Metropolis Nigeria. *Biosc. Res. Comm., 22(6).* Retrieved from http://www.klobex.org/brc on 15 November 2016.

Jeje, C. Y. and Fernando, C. H. 1986. *A practical guide to the identification of Nigerian zooplankton.* Kainji Lake Research Institute, Niger, Nigeria.

Lalli C. M. and Parsons, T. R. 1993. *Biological oceanography: An introduction.* Elsevier, p. 314.

Lind, O. T. 1979. *A Handbook of Limnological Methods.* CV Mosby Co. St. Louis, 199pp.

Lynne M. W. 2004. *Practical Guide to Identifying Freshwater Crustacean Zooplankton.* Cooperative Freshwater Ecology, 2nd Edition.

Mackreth, F. J. H. 1963. Some methods of water analysis for limnologists, scientist publications. *Freshwater Biol. Ass. 21:* 71.

Nlewadim, A. A. and Adeyemo, A. A. 1998. Effect of Inorganic Fertilization on Zooplankton Production in Brackish Water (eds). Selected Papers from 9th/10th Annual Conference of the Nigerian Association for Aquatic Sciences. University of Agriculture, Abeokuta, Ogun

State 30th November-2nd December 1995, pp. 75-82.

Obertegger, U. and Manca, M. 2011. Response of rotifer functional groups to changing trophic state and crustacean community. *Jour. of Lim., 70(2):* 231-238.

Okogwu, O. I. and Ugwumba, O. A. 2006. The zooplankton and environmental characteristics of Ologe Lagoon, South West Nigeria. *The Zoologist, 4:* 86-92.

Ovie, S. I. 1997. The Ecology and Culture of the Zooplankton of Jebba Lake, Nigeria, Ph.D Thesis, University of Benin, Benin City, Nigeria, 240pp.

Park, K. S. and Shin, H. W. 2007. Studies on phytoplankton and zooplankton composition and its relation to fish productivity in a west coast fish pond ecosystem. *Jour. of Envi. Boil., 28:* 415-422.

Perry, R. 2003. A guide to the marine plankton of southern California http://www.msc.ucla.edu/oceanglobe retrieved 28 July, 2013.

Redmond, W. A. 2008. 'Lead' Microsoft ® Encata® 2007 [DVD] Micosoft Corporation 2007.

Sutherland, W. J. 1998. *Ecological Census Techniques*, Cambridge University Press, 336pp.

Tanko, D., Ezealor, A. U. and Bako, S. P. 2013. Current Status of the Woody Vegetation of Dumbi Inselbergs and its Surroundings, Zaria Northern Guinea Savanna, Nigeria. *Nig. Jour. of Sci. Res., 11 and 12:* 1-9.

Tanko, D., Ezealor, A. U. and Bako, S. P. 2014. Community structure and abundance of avian and non-avian vertebrate fauna of Dumbi Inselberg and Adjacent Woodland in Zaria, northern, Nigeria. *The Zoologist, 12:* 46-53.

Citation: Tanko, D., Chia, M. A. and Nuhu, G.
Zooplankton community structure and dynamics during the transition from dry to rainy season: A case study of Kufena Inselberg (Rock) Pool, Zaria, Nigeria.
The Zoologist, 14: 7-13 December 2016, ISSN 1596 972X.
Zoological Society of Nigeria.