Influence of Physico-Chemical Parameters on the Biodiversity and Distribution of Macro-Invertebrates along the Coastline of Great Kwa River, Southeast Nigeria.

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Abstract: Studies were conducted between July and September in the Great Kwa River, Nigeria on the influence of physico-chemical parameters on the biodiversity and distribution of macro-invertebrates. The species composition of the macrobenthos identified during the period of study consisted of 8 macrobenthos belonging to 4 macrobenthic groups were identified. These were Annelida (*Oligochaeta*) (*Glycera convoluta*), Mollusca (Bivalvia) (*Egeria paradoxa*), Mollusca (Gastropoda) (*Nerita afra* and *Pachymelania aurita*), Palaemonidae (Crustacea) (*Cardisoma armatum*, *Macrobranchium vollenhovenii, M. Macrobranchion* and *M. equidens*. Results of the study also revealed that there were variations in the physico-chemical parameters during the period of study. Temperature ranged between 25.4 – 25.8^{0}C with a mean of 25.6 ± 2.28^{0}C at Station 1 in July, with a range between 25.4 – 25.9^{0}C with a mean of 25.6 ± 2.22^{0}C at Station 2, while in August, temperature ranged between Station 1, with a range of between 25.1 – 25.5^{0}C with a mean of 25.3 ± 2.24^{0}C at Station 2. In September, temperature ranged between 25.5 – 25.6^{0}C with a mean of 25.5 ± 2.25^{0}C at Station 1, and a range of 25.6 – 25.7^{0}C with a mean of 25.65 ± 2.25^{0}C at Station 2. pH ranged between 5.64 – 5.66 with a mean of 6.65 ± 1.54 at Station 1 in July, 6.63 – 5.73 with a mean of 5.67 ± 1.54 at Station 2 and between 6.58 – 6.71 with a mean of 6.65 ± 1.54 in August at Station 1, 6.58 – 6.72 with a mean of 6.65 ± 1.54 at Station 2, while in September, pH ranged between 5.72 – 5.74 with a mean of 6.73 ± 1.55 at Station 1 and between 6.54 – 6.78 with a mean of 6.66 ± 1.54 at Station 2. Dissolved oxygen (DOmgL^{-1}) ranged between 5.84 – 6.4mgL^{-1} with a mean of 6.16 ± 1.58mgL^{-1} in July at Station 1. At Station 2 dissolved oxygen maintained a fixed value of 5.0mgL^{-1} with a mean of 5.0 ± 0.0mgL^{-1} in July and August at both Stations, while in September, a DO range of between 5.4 – 5.6mgL^{-1} with a mean of 5.5 – 1.53mgL^{-1} was recorded at Station 1, and a range of 5.0 - 5.4^{0}C with a mean of 5.2 ± 1.51mgL^{-1} at Station 2. Salinity was not detected in the river water throughout the period of study. Higher number of macrobenthos were sampled at Stations and Months of high dissolved oxygen, low temperature and slightly acidic content. Ecological indices of the macrobenthos of the Great Kwa River, Nigeria were also observed to vary at each station. At station 1, 4 macrobenthic phyla were recorded with 3 phyla at station 2, while total of 895 individual macrobenthos were recorded at station 1 with 882 individuals at station 2. Margalef's index (d) was 0.882 at station 1 with an index of 0.737 at station 2, while Shannon-wiener index (H) was 2.945 at station 1, with an index of 2.940 at station 2. Simpson's index of dominance (D) was 0.00052 at station 1 with an index of 0.00038 at station 2. Significant relationship (p>0.05) was found between macro invertebrate abundance and physico-chemical parameters.

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Introduction

Macro-invertebrates are organisms that lack a spine and are large enough to be seen with the naked eye. They are also known as a diverse array of animals without backbones and operationally defined as those that are retained by a sieve or mesh with pores size of 0.2 to 0.5 mm, as used most frequently in stream and river sampling devices (Winterbourn, 1999). Fresh water macro-invertebrates include various groups of worms (flatworms, eelworms and segmented round-worms), molluscs (snails and bivalves), crustaceans (shrimps, crayfish and other shrimp-like groups), mites, and above all insects (Winterbourn, 1999). Much of the ecosystem functioning and biodiversity in running water is explained by macro-invertebrates because they serve as an important contributors in detritus processing, animal-microbial interaction and energy transfer to the consumers at higher trophic levels (Allan, 1995; Wallace and Webster, 1996). They graze periphyton (and may prevent blooms in some areas), assist in the breakdown of organic matter and cycling of nutrients and, in turn, may become food for predators (e.g. fish) (Hynes, 1970; Jimoh *et al*., 2011; Uwem *et al*., 2011). Macro-invertebrates are the organisms most commonly used for biological monitoring of freshwater ecosystems worldwide. This is because they are found in most habitats, have generally limited mobility, are quite easy to collect by way of well establish sampling techniques.

Macro-invertebrates are heterogenic collections of various evolutionary taxa, where their biotic and diversity indices are used to determine water quality and pollution changes in the streams/rivers. Furthermore, there is an entwining relationship between water quality of streams/rivers and macro-invertebrate diversity. This is because water is an important and essential substance in protoplasm and is the basis of life. It has been responsible for evolving life in our planet. It represents the great circulation system of the earth, being a component of the sap of plants, the blood stream of animals, and rainfalls on the surface of the lands of rivers flowing to the sea. In addition, water also forms a single worldwide resource distribution on land, sea and atmosphere and unified by hydrological cycle without which life would not be maintained. About 2/3 of the earth surface is covered with water (Smith, 1974).

Water serves as a home to a wide variety of organism, both aquatic plants and animals. Hence, the quality of the water determines the level of abundance of these organisms. This implies that the influence of the physical and chemical parameters of a river must be such that permits the growth and development of aquatic organisms, though a few can survive extremes. However, it is argued that the physical and chemical condition of many streams and rivers in tropical and sub-tropical countries is deteriorating as a result of human population explosions, anthropogenic effects from land use, intensified agricultural practices and increased industrialization, all of which cause changes to natural flow regimes directly or indirectly (Pringle *et al*., 2000; Wishart *et al*., 2000). Parameters such as temperature, turbidity, nutrients, hardness, alkalinity, dissolved oxygen, etc. are some of the important factors that determines the growth of living organisms in the water body.

Increased temperatures can have important consequences for stream organisms. Bioenergetic studies indicate a strong positive relationship between feeding rates and metabolism with temperature for both fish and insect communities (Gibbons, 1976; Wotton, 1995). Increased metabolic rate carries with it a need for increased levels of food quantity or quality in order to maintain growth and survival rates (Wotton, 1994). However, temperatures must not exceed the biological preferences of typical cold-stenotherms (i.e. 20 °C), if cold-water fauna are to prosper downstream (Allan, 1995; Giller and Malmqvist, 1998; Taniguchi *et al*., 1998).

At present, in many regions of the world, the salinity of inland waters has been increasing (Williams, 1987; Stoner, 1988; Velasco *et al*., 2006). Under the conditions of global climate changes, the process of salinization leads to changes in biotic components in water bodies and watercourses. Thus the studies of the salt sensitivity of aquatic animals, which is one of the key abiotic factors that affect hydrobionts, are of primary importance (Aladin, 1996). Macrozoobenthos is one of the main components of biota in highly mineralized lotic systems in which the impact of salinity on bottom communities depends mainly on the salt sensitivity of some species (Schmidt Nielsen, 1982; Williams and Williams, 1998). Therefore the threshold of salt sensitivity of various taxa can be estimated by the maximum salinity at which species occur in natural waters, as well as in the course of the experiment during which the animals are exposed to the effect of different salt concentrations (Filenko and Mikheeva, 2007; Berezina, 2003; Echols *et al*., 2009).

Oxygen availability is a widely recognized factor influencing the composition of freshwater communities because it critically affects the distribution of many species (Hynes, 1960; Giller and Malmqvist, 1998; Dodds, 2002). Dissolved oxygen (DO) concentrations can vary spatially and temporally because of respiration by organisms, photosynthesis by plants, atmospheric losses and gains, changes in pressure and temperature, and groundwater inflow (Hynes, 1970; Allan, 1995; Dodds, 2002). Anthropogenic impacts have increased the frequency, duration, and intensity of hypoxia in many aquatic systems, resulting in changes in community composition and often a loss of diversity (Hynes, 1960; Pearson and Penridge, 1987).

The effects of pH on fish and other freshwater aquatic life have been reviewed in detail (Doudoroff and Katz, 1950; McKee and Wolf, 1963; EIFAC, 1969; Katz, 1969; NAS, 1972; AFS, 1979; Alabaster and Lloyd, 1980). The pH of water affects the normal physiological functions of aquatic organisms, including the exchange of ions with the water and respiration. Such important physiological processes operate normally in most aquatic biota under a relatively wide pH range (e.g. 6-9 pH units). There is no definitive pH range within which all freshwater aquatic life is unharmed and outside which adverse impacts occur. Rather, there is a gradual "deterioration" in acceptability as pH values become further removed from the normal range (EIFAC, 1969; AFS, 1979; Alabaster and Lloyd, 1980). The acceptable range of pH to aquatic life, particularly fish, depends on numerous other factors, including prior pH acclimatization, water temperature, dissolved oxygen concentration, and the concentrations and ratios of various cations and anions (McKee and Wolf, 1963).

Natural organic detritus and organic waste from waste water treatment plants, failing septic systems, and agricultural and urban runoff, act as a food source for water-borne bacteria. Bacteria decompose these organic materials using dissolved oxygen (DO), thus reducing the DO present for fish. By definition, biochemical oxygen demand (BOD) is a measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions. Biochemical oxygen demand is determined by incubating a sealed sample of water for five days and measuring the loss of oxygen from the beginning to the end of the test. Samples often must be diluted prior to incubation or the bacteria will deplete all of the oxygen in the bottle before the test is complete.

This research will highlight the health status of the Great Kwa River by assessing its physico-chemical parameters and how these parameters affect its macro-invertebrate diversity and abundance. This information will form a reference point for further and periodic reviews of the water status of the Great Kwa River and guard against any negative impact on the fauna and flora of the river, occasioned by anthropogenic activities and environmental changes with the following specific objectives.

1. To assess the diversity and distribution of macro-invertebrates in the Great Kwa River.
2. To assess the gradation of the physico-chemical parameters at the designated stations along the Great Kwa River.
3. To ascertain the effect of the physico-chemical parameters on macro-invertebrates in the Great Kwa River.

2. Biodiversity and Distribution of Macroinvertebrates

Macroinvertebrates are animals without backbones. Those that are adapted to aquatic life have representatives in a variety of animal groups that include hydras, worms, molluscs and arthropods. Some of them are large enough to be seen with the naked eye, though, in some cases, their detailed characteristics can only be appreciated with the aid of a dissecting microscope or an appropriate magnifying lens (Ajuzie, 2012).

Aquatic macro-invertebrates are very resourceful to man. Eyo and Ekwuonye (1995) working on the macroinvertebrate fauna of pools in the flood plain (fadama) of the Anambra River observed that macro-invertebrates served as food. Wissmar and Wetzel (1978), Boisclair and Legget (1985) and McQueen *et al*., (1986) reported that macroinvertebrate community in the littoral zone of lakes are a crucial link in the transfer of energy from primary producers to fish. Macro-invertebrates in the littoral zones of lakes are crucial links in the transfer of energy from producers and detritus to fish (Hanson, 1990) and to water fowl (Danell and Sjoberg, 1982).

Macroinvertebrates of the shores of the Great Kwa River were sampled by Okorafor*et al*., (2012) monthly between August 2011 and January 2012 using the kick sampling technique and Van Veen Grab methods. The distribution of organic matter, substratum texture and current velocity accounted for the variations of species composition, taxonomic richness and total abundance at the two stations. The most dominant taxonomic order was Decapoda represented mostly by *Litopaenaeusvannamei* (84.3%) followed by *Johngarthialogostoma* (4.45%) and Lymnaea species (4.85%) in Gastropoda. The abundance of *Litopaenaeusvannamei* is attributed to the fact that they are filter feeders that feed on the mud particles. High human activities around station two, resulting in releasing waste into the river, accounted for the poor species richness.

Ajuzie (2012) investigated the taxon richness of macroinvertebrates in two tropical neighbouring reservoirs located in the biotite granite-rock strewn Lamingo village in Jos North Local Government Area of Plateau state, Nigeria. These two reservoirs were subjected to different levels of human interferences. The overall idea was to provide a preliminary inventory (baseline data) of macroinvertebrate taxa in the two water bodies that will serve as references for future works in the reservoirs. A pond net was used to sample the benthic zone at the shallower parts of the reservoirs' littoral zone, in a shovel- and rake-like manner. Benthic matter (mud, silt, sand, small gravels and detritus as well as associated invertebrates) collected was washed through a vegetable sieve and then through a tea sieve, procedures which made it possible to pick out and sort the macroinvertebrates. Captured animals were identified to family level. Lamingo reservoir had more taxa than Liberty reservoir. Out of the 199 animals recorded for the two reservoirs, 80.40 % were recorded in samples collected from Lamingo reservoir. A striking observation was that whereas molluscs (gastropods and bivalves) were present in samples collected from Lamingo reservoir, no mollusc was recorded in samples collected from Liberty reservoir. The fewer taxa recorded for Liberty reservoir could be as a result of ecological disturbance occasioned by human activities (farming on the catchment area, extraction of water for crop farming, silviculture, and for block moulding, as well as water tankers driving into the reservoir to collect water). Lamingo reservoir is far less disturbed.

Olson *et al*., (1999) researched on the abundance and distribution of macroinvertebrates in relation to macrophyte communities in Swan Lake, Nicollet County, MN. They compared the macroinvertebrate communities among vegetation types in Swan Lake, a large prairie marsh in south-central Minnesota. Activity traps and sweep nets were used to sample macroinvertebrates during the summer months of 1992 and 1993. Twenty-four sites on the lake were sampled along six established transects. Each site was located in one of four different habitats, including three major macrophyte communities: Typhaangustifolia, Scirpusacutus, Potamogeton spp. and an open water site having little or no vegetation. The diversity, relative abundance, and biomass of the invertebrates collected from each vegetation type were compared to assess which type of vegetation supported the greatest numbers and most diverse invertebrate fauna. A total of 16 orders, 46 families and 93 genera were identified. Results suggest that the open water sites produced the largest number of organisms, whereas the Typha sites produced the largest total biomass of invertebrates. Nine orders showed a significant difference in abundance between vegetation communities, but there was not a significant difference of any order in biomass between vegetation types. There was a significant difference in the mean diversities between vegetation community types. Typha sites supported the most diverse populations of macroinvertebrates and the open sites produced the least diverse populations. The abundance of six orders was significantly different between years and may be attributed to fluctuating water levels. Their results suggest that the occurrence and abundance of certain macrophyte communities may enhance the quality of a marsh for consumers of macroinvertebrates.

2.1 Direct Effects of pH on Aquatic Life

Alabaster and Lloyd (1980) identified the pH range that is not directly lethal to freshwater fish as 5.0-9.0. With few exceptions, pH values between 6.5 and 9.0 are satisfactory, on a long-term basis, for fish and other freshwater aquatic life. The pH of most inland fresh waters containing fish, ranges from about 6 to 9 (Ellis, 1937), with most waters, particularly those with healthy, diverse, and productive fish and macroinvertebrates communities having a pH between approximately 6.5 and 8.5 units (Ellis, 1937; McKee and Wolf, 1963; NTAC, 1968; NAS, 1972). In establishing water quality criteria for pH, ORVWSC (1955) stated that, although fish had been found at pH values from 4-10, the safe range was 5-9 and for maximum productivity the pH should be maintained between 6.5 and 8.5. Some aquatic organisms (e.g. certain species of algae) have been found to live at pH 2 and lower and others at pH 10 and higher (NAS, 1972). However, there are few such organisms, and their extreme tolerances are not reflective of the pH tolerated by the majority of organisms occurring in a given aquatic ecosystem.

Bernard *et al*., (1990) during his research on acidified experimental reaches of a British Columbia stream from pH 7.0 to 5.9 within 30 minutes to assess the effect of mild acidification on short-term invertebrate drift, reported that small Ephemeroptera showed no initial response to pH reductions from 7.0 to 5.9, but that their drift increased after about 6 hours. Increased drift was observed for Chironomid and Trichoptera within an hour of reaching pH 5.9. Harpactacoid copepods, Hydrcarina, simulid Diptera, Plecoptera, and large Ephemeroptera did not respond. Lack of a drift response induced by rapid pH reduction in certain taxa demonstrates that the organisms were not adversely affected enough to move, and consequently, would not be affected enough to experience mortality. Kratz*et al*., (1994) reported that Simuliids (black flies) did not respond to rapid depressions of 1 pH unit below ambient, with an ending pH of below 6.0. Also, Hall *et al*., (1987) reported no effect on daytime drift rates in acidic Norris Brook, where pH was reduced from 6.4 to 5.2-5.5. Bernard *et al*., (1990) surmised that the rapid, large increases in drift exhibited by chironomids were avoidance behavior. Sensitive organisms may escape by drift to more suitable conditions downstream. Bernard (1985) (cited in Bernard *et al*., 1990) supported this hypothesis by showing that rapidly responding mayflies collected in a stream rapidly acidified to pH 5.7, had greater than 95% survival when subsequently held in circumneutral water for 24 hours. Kratz *et al*., (1994) concurred with these findings, suggesting that mild pH reductions (i.e. those with an ending pH near 6.0 or above) would likely elicit increased drift in some species due to behavioural responses rather than from causing pH-related mortality, whereas mortality-induced drift would increase as ending pH decreases, and reached lethal levels (e.g. 5.5 or lower).

Furthermore, a research on the effects of pH on fish and other freshwater aquatic life (USEPA, 1976; 1986) concluded that a pH range of 6.5 to 9.0 provides adequate protection for the life of freshwater fish and bottom-dwelling macroinvertebrates. Outside this range, fish suffer adverse physiological effects that increase in severity as the degree of deviation increases until lethal levels are reached (USEPA, 1976; 1986).

2.2 Effect of Low Dissolved Oxygen on Survival of Macroinvertebrates in Tropical Rivers

Dissolved oxygen is important and is required for the existence of aquatic life. Dissolved oxygen is required for respiration and release of energy from food (Lagleret a!., 1977). According to Adeniji (1986), its presence in good quantity in water will improve the water quality by converting poisonous gases like hydrogen sulphide, ammonia, etc into their non-poisonous forms. Dissolved oxygen content of water results from the photosynthetic and respiratory activities of the biota in the open water, the aufwuchs, the diffusion gradient at the air-water interphase and distribution by wind.

Connolly *et al*., 2004 measured the effect of different Dissolved Oxygen (DO) concentrations on the macroinvertebrate assemblages from 2 Australian tropical streams (1 upland, 1 lowland) using artificial stream mesocosms. Responses to 5-d exposures were tested. Both the upland and lowland assemblages showed a similar response. Most taxa tolerated all but very low DO levels (10% saturation), although a reduction in emergence of insect taxa at intermediate levels (25–35% and 10–20% saturation) was observed. Mayflies showed the highest sensitivity to low oxygen conditions, and lethal effects were observed at DO levels 20% saturation for several upland and lowland species. For other taxa, including several Chironomidae, mortality was observed when oxygen concentrations were below 8% saturation. A drift response was observed only when oxygen concentrations reached near lethal levels (10% saturation). The lack of a drift response at DO concentrations of 25 to 35% and 10 to 20% saturation indicates that, in moderately poor oxygen conditions, macroinvertebrates will remain at a location and, hence, experience sublethal effects such as suppressed emergence. It is clear that these animals can persist in hypoxic conditions in the short term. However, because of sublethal effects, understanding how low DO concentrations affect natural assemblages of aquatic macroinvertebrates may require studies of populations over several generations.

Jacobsen (2007) explored the altitudinal decrease in local richness of stream macroinvertebrates. He compared the explicatory power of a mid-domain effect (MDE) null model and a number of selected contemporary ecological variables, with a special emphasis on the altitude-mediated decrease in temperature and oxygen availability as possible driving factors for the observed pattern. Benthic macroinvertebrates were sampled at 30 stream sites between 2,600 and 4,000 m a.s.l. in northern Ecuador. All four measures of local richness (total number of taxa, taxa in Surbers samples, Fisher's index and rarefied richness) decreased with increasing altitude. The MDE null model, water temperature and dissolved oxygen also decreased with altitude, while other measured variables were uncorrelated with altitude. Minimum oxygen saturation had the highest explanatory power of the density-corrected Fisher's and rarefied richness ($R = 0.48$ and 0.52, respectively), but also minimum temperature ($R = 0.48$ and 0.41) and the MDE null model ($R = 0.48$ and 0.46) correlated significantly. Multiple regression analyses using several predictive variables showed that oxygen saturation had the greatest and only significant effect on density-corrected richness. The relationship between richness and oxygen corrected for the effect of altitude (using analyses of double residuals) was signify-cant, whereas that of richness versus temperature was not. The results indicate that the decrease in richness with increasing altitude is mainly caused by a decrease in oxygen saturation rather than by a decrease in temperature. Levels of oxygen saturation such as those found at high altitudes do not appear to be lethal to any species, but could affect macroinvertebrates through long-term, sub-lethal effects. I suggest that low oxygen availability may limit biodiversity at high altitudes not only in the aquatic, but also in the terrestrial environment.

Garmmon and Reidy (1981) stressed the important role that tributaries play during episodes of low dissolved oxygen. They noted that, under normal or high flow conditions, fish commnunities in tributaries to the middle Wabash River, Indiana, tended to be smaller, less diverse, and of a different species composition than fish conmunities in the mainstem. In late July and early August 1977, dissolved oxygen concentrations declined to a low of 1.0 mg/liter in a 35-mile stretch of the river. During that period, pollution-sensitive fishes moved into the mouths of tributaries, increasing several caununity indices. Such movements to avoid stress conditions in the Wabash mainstem have been hypothesized by Gammon (1976). Previous work by Cross (1950), Minckley (1963), and Krumholz and Minckley (1964) documented this phenomenon in other rivers.

2.3 Influence of Temperature on Aquatic Organisms

Lessard and Hayes (2003) in their research reported that many studies have investigated the ecological changes that occur below dams that release cold, hypolimnetic water, but very few studies have looked at the effects of the release of warm, surface waters. The effect of small, surface release dams on downstream thermal regimes is a major habitat concern for many cold-water systems, however. The objective of this study was to examine the effects of summer temperature increases due to impoundment on downstream fish and macroinvertebrate communities in cold-water streams. We sampled fish, macroinvertebrates and habitat upstream and downstream of dams on ten rivers during the summers of 1998 and 1999. Changes in mean summer temperature downstream varied from a cooling of 1°C to an increase of more than 5°C. Increasing temperatures downstream coincided with lower densities of several cold-water fish species, specifically brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*) and slimy sculpin (*Cottus cognatus*) while overall fish species richness increased downstream. Density of mottled sculpin (*Cottus bairdi*), another cold-water species, was not related to temperature changes below the dams. Macroinvertebrates showed shifts in community composition below dams that increased temperature. This study provides information useful for determining the extent of impact of these small, surface release dams, which are abundant across the country.

Similarly, Snyder and Blahm (1971) on their research on the effects of increased temperature on cold-water organisms stated that thermal pollution is one of the problems that man must resolve if he wishes to maintain the quality of his environment. It is predicted that thermonuclear electric power will increase 16-fold in the Pacific Northwest and equal that of hydroelectric power by 1985. Without adequate controls, adverse conditions could be produced by discharge of waste heat into the aquatic environment. Uncontrolled releases of heat can destroy, dislodge, or debilitate portions of the aquatic biota. Controlled releases of heat, however, may even benefit some organisms. Increased water temperatures will not only delay migrations of anadromous fish but also induce direct or indirect stresses and contribute to serious disease problems, and it will favour some species of fish that compete with (and prey on) important stocks of salmon and trout. It is more likely to benefit saltwater habitats, especially man-made canals, ponds, and raceways, than freshwater habitats.

Furthermore, Burgmer*et al.*, (2007) in their research on the effects of climate-driven temperature changes on the diversity of freshwater macroinvertebrates reported that increasing temperatures due to climate change were found to influence abundance and timing of species in numerous ways. Whereas many studies have investigated climate-induced effects on the phenology and abundance of single species, less is known about climate-driven shifts in the diversity and composition of entire communities. Analyses of long-term data sets provide the potential to reveal such relationships. We analysed time series of entire communities of macrozoobenthos in lakes and streams in Northern Europe. There were no direct linear effects of temperature and climate indices (North Atlantic Oscillation index) on species composition and diversity, but using multivariate statistics we were able to show that trends in average temperature have already had profound impacts on species composition in lakes. These significant temperature signals on species composition were evident even though we analysed comparatively short time periods of 10–15 years. Future climate shifts may thus induce strong variance in community composition.

Dallas *et al*. (2013) while researching on Sub lethal effects of temperature on freshwater organisms, with special reference to aquatic insects reported that Water temperature is a key variable affecting aquatic organisms. Understanding their response to elevated water temperatures is important for estimating upper thermal limits, and ultimately for assisting with setting defendable, biologically-relevant water temperature guidelines for lotic systems. Sub lethal effects impacting on an individual organism or species may manifest at higher levels of the hierarchy, namely, populations, communities and entire ecosystems. Sub lethal effects typically include those affecting an organism's physiology and metabolism (e.g. growth rates, secondary productivity, respiration); phenology (e.g. development time, voltinism, emergence); reproductive success and fitness (e.g. fecundity, rates and success of egg development and hatching); behaviour (e.g. migration, movement, drift); and broad-scale ecological effects (e.g. species richness, composition, density, distribution patterns). Sub lethal effects are discussed with examples drawn from freshwater studies, in particular those focused on aquatic insects. Commonly-used methods, which vary from simple, cost-effective, laboratory-based methods to more elaborate, expensive, laboratory- and field-based studies, are assimilated to serve as a toolbox for future thermal research. Ultimately, the method adopted depends largely on the question (s) being asked and available resource.

3. Methodology

3.1 Description of the Study Area

The Great Kwa River originates in the Oban Hills, in the Cross River National Park and is located between latitude 80 15'E and 80 30'E and longitude 40 45'N and 50 15'N. It has an estimated length of 56km and is about 2.8km wide at the mouth where it empties into the cross river estuary (Okorafor *et al*., 2012).

3.2 Climate

Two climatic seasons, wet and dry, prevail in the study area and the wet season is characterized by high rainfall while the dry season experiences occasional downpours. The shorelines are lined with dark mud plates usually exposed during low tides. The water at the shore being brackish is rich in macroinvertebrates and debris (Okorafor *et al*., 2012).

3.3 Vegetation

The banks of this study area are surrounded by lush evergreen, forest vegetation with different species of trees, shrubs and grasses.

3.4 Human Activities

Human activity in the Great Kwa River has traditionally been limited to small scale farming, aquaculture and artisanal fisheries, mainly for shrimp. However, Calabar is growing, due in part to the Calabar Free Trade Zone, causing growing numbers of houses and factories to be built in the freshwater and mangrove swamps of the Great Kwa River.

Fig.1: Map of the Great Kwa River showing sampling stations

Three sampling stations are selected for this study.

Station 1: This station is located at Obufa Esuk, close to the university of Calabar staff quarters. Its coordinates are 04° 56' 24'N and 008° 21' 11'E. The substratum here is covered by mud or clay with an average depth of 0.2m. It is swift-flowing and has a low transparency. The vegetation here includes fan palm (*Hyphaene petersiana*) and grasses (Okorafor *et al*., 2012).

Station 2: This station is located at EsukAtu, close to the Biological Sciences Faulty and Teaching Hospital areas of the University of Calabar. Substratum here is covered with coarse sand and mud with an average depth of 0.2m. It is swift-flowing and has medium transparency. Vegetation here includes elephant grasses, palm and trees (*Elaeis guineensis*) and fan palms (*Hyphaene petersiana*) (Okorafor *et al*., 2012).

Station 3: This station is located at EsukAtimbo, a populated place in Calabar. Its coordinates are 04° 55' 6'N and 008° 24' 0'E.Vegetation here includes elephant grasses, palm trees (*Elaeis guineensis*) and fan palms (*Hyphaene petersiana*).

3.5 Field Studies

Prior to the time for the work, a reconnaissance survey was carried out in order to understand the study site and also know the materials to be used for the studies.

Sampling of macro-invertebrates was carried out for a period of three (3) months at monthly intervals between July and September, 2017. During this period, sampling was done between 0700 and 1200 hours on each sampling day.

For the parameters, Temperature was measured in-situ with mercury in glass thermometer, pH was measured in-situ with a pocket pH scale, Salinity was measured in-situ with a refract meter and Dissolved oxygen was measured in-situ with a Dissolved Oxygen meter (hand-held).

The macro-invertebrates collected were put into plastic containers containing formalin before taken to the laboratory for identification and classification.

3.6 Laboratory Studies

3.6.1 Identification/classification of macroinvertebrates

The macro-invertebrates were poured into a white plastic tray, stained with Rose Bengal Solution and sorted using forceps into different groups. Rose Bengal solution enhances the benthic organisms to be clearly seen even with the naked eyes (Narita *et al.*, 2003; Hart, 1999). They were identified under a compound microscope using the keys and guide of Environmental Protection Agency and counted (EPA, 1998).

3.7Ecological indices

The determination of each of ecological indices (Margalef's and Shannon-wiener) was based on the formulae contained in Margalef (1965); Ogbeidu (2005) and Job *et al.* (2017).

(i) Margalef (species diversity) index (d):

$d = \frac{s-1}{\ln(N)}$ (Margelef 1965)

Where,

s = the total number of species

N = the total number of all individuals

In = Naperian or natural logarithm

(ii) Shannon-wiener index (H):

$H = \frac{N\log^{N} - filosf\,i}{N}$ (Ogbeibu, 2005)

Where,

N = the total number of all individuals

fi = the total number of species per phyla

3.8 Statistical Analysis

Data were presented in Tables with mean values and standard deviations of each of the physico-chemical parameters calculated. Analysis of variance (ANOVA) wasused to test for statistical differences between the means of the physical and chemical parameters of the three sampling stations and macrobenthos abundance in the river system.

Table 1: Station-by-station variations in the physico-chemical parameters of the Great Kwa River, Nigeria, during the period of study (July - September, 2017).

Physico-Chemical Parameters	JULY						AUGUST						SEPTEMBER					
	STATION 1			STATION 2			STATION 1			STATION 2			STATION 1			STATION 2		
	Day 1	Day 2	Mean	Day 1	Day 2	Mean	Day 1	Day 2	Mean	Day 1	Day 2	Mean	Day 1	Day 2	Mean	Day 1	Day 2	Mean
Temperature ℃	25.8	25.4	25.6±2.24	25.9	25.4	25.6±2.25	25.3	25.55	25.43±2.25	25.1	25.5	25.3±2.24	25.5	25.6	25.55±2.25	25.6	25.7	25.65±2.25
Hydrogen ion conc. pH	5.66	5.64	5.65±1.54	5.60	5.73	5.67±1.54	5.71	5.58	5.65±1.54	5.58	5.72	5.65±1.54	5.74	5.72	5.73±1.55	5.54	5.78	5.66±1.54
Dissolved Oxygen mgl	6.47	5.84	6.16±1.58	5.0	5.0	5.0 ± 1.50	5.0	5.0	5.0 ± 1.50	5.0	5.0	5.0±1.50	5.4	5.6	5.5±1.53	5.4	5.0	5.2±1.51
Salinity ‰	0	0	0±0	0	0	0±0	0	0	0±0	0	0	0±0	0	0	0±0	0	0	0±0

Station 1 = Esuk Atimbo Station 2 = Esuk Atu

Table 1a: WHO and FEPA permissible limits for the investigated physico-chemical parameters comparing obtained values during the study

Physico-chemical parameters	WHO (2003)	FEPA (1971)
Temperature ℃	25.0 – 30.3	25.0 – 30.3
PH	6.5 – 8.5	6.0 – 9.0
Dissolved Oxygen mgL	7.5	7.7
Salinity ‰	-	-

The mean values of the physico-chemical parameters were also observed to fall within the WHO and FEPA permissible limits for enhanced primary productivity (WHO, 2003; FEPA, 1971) (Table 1b).

The total abundance of the macrobenthos ranged between 206 – 369 at Station 1, with 369 macrobenthos sampled in July, 329 in August and 206 in September, giving an overall abundance of 904 at the Station (Station 1), while at Station 2, total of 370 macrobenthos were sampled in July, 271 in August and 252 in September, giving an overall abundance of 893 (Table 1b).

Higher number of macrobenthos were sampled at Stations and Months of high dissolved oxygen, low temperature and slightly acidic content.

Table 1b: Summary of the station-by-station mean values of the physico-chemical parameters of the Great Kwa River, Nigeria (July – September, 2017).

Parameters	Station 1						Station 2	
	July	August	September	N*	July	August	September	N*
Temperature (^{0}C)	25.6±2.28	25.43±2.24	25.55±2.25		25.65±2.23	25.3±2.24	25.05±2.25	
pH	6.65±1.54	6.65±1.54	6.73±1.55		6.67±1.54	6.65±1.54	6.66±1.54	
DO (mg^{-1})	6.16±1.58	5.0±0.0	5.5±1.53		5.0±0.0	5.0±0.0	5.2±1.51	
Salinity (%00)	0±0.00	0±0.00	0±0.00		0±0.00	0±0.00	0±0.00	
Macrobenthos abundance	369*	329*	209*	904	370*	271*	252*	893

Stn 1 = Atimbo Beach, Stn 2 = Atu Beach, Station 3 () was not accessible due to security challenges during the period of sampling.

* = Monthly abundance

N* = Overall abundance of the macrobenthos from all the months of sampling

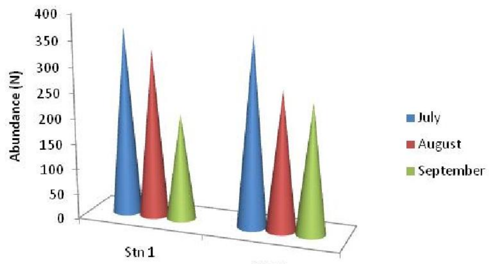

Fig. 2: Monthly abundance of the macrobenthos per station of sampling, Great Kwa River, Nigeria, during the period of study (July – September, 2017).

The species composition of the macrobenthos identified during the period of study are presented in Table 2. Total of 8 macrobenthos belonging to 4 macrobenthic groups were identified. These were Annelida (*Oligochaeta*) (*Glycera convoluta*) (Plate 1), Mollusca (Bivalvia) (*Egeria paradoxa*) (Plate 2), Mollusca (Gastropoda) (*Nerita afra* (Plate 3) and *Pachymelania aurita*) (Plate 4), Palaemonidae (Crustacea) (*Cardisoma armatum* (Plate 5), *Macrobranchium vollenhovenii* (Plate 6), *M. Macrobranchion* (Plate 7) and *M. equidens* (Plate 8).

Plate 1: *Glycera convolute* (Annelida: Oligochaeta)

Plate 2: *Egeria paradoxa* (Mollusca: Bivalvia)

Plate 3: *Nerita afra* (Mollusca: Gastropoda)

Plate 4: *Pachymelania aurita* **(Mollusca: Gastropoda)**

Plate 5: *Cardisoma armatum* (Palaemonidae: Crustacea)

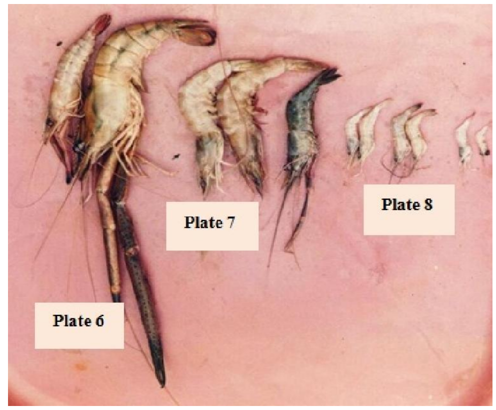

Plate 6: *Macrobrachium vollenhovenii* (Palaemonidae: Crustacea)
Plate 7: *M. macrobrachion* (Palaemonidae: Crustacea)
Plate 8: *M. equidens* (Palaemonidae: Crustacea)

Table 2: Species composition of the macro-benthos in the great Kwa River, Nigeria, (July – September, 2017) (Pooled Results).

	Station 1		Station 2		Marginal total
Macrobenthic species	Number of individuals (n)	%n	Number of individuals (n)	%n	
Annelida					
Glycera convoluta	1		-		
Total abundance (n)	1	100	-	-	1
Mollusca (Bivalvia)					
Egeria paradoxa	4	100	7	100	
Total abundance (n)	4	100	7	100	11
Mollusca (Gastropoda)					
Nerita afra	134	43.94	183	78.8	
Pachymelania aurita	171	56.06	49	21.12	
Total abundance (n)	305	100.0	232	100.0	537
Palaemonidae (crusacea)					
Macrobranchiumvollonhovenii	224	38.29	238	37.01	
Macrobranchiummacrobrachion	218	37.26	189	29.39	
Macrobrachiumequidens	143	24.44	216	33.59	
Total abundance (n)	585	99.99 ≈ 100	643	99.99 ≈ 100	1228

Station 1 = Esuk Atimbo
Station 2 = Esuk Atu
Station 3 = Obufa Esuk. But there was no access to this third station due to security reasons.

Table 3: Summary of the numerical (n) and relative abundance (%Ra) of the major macrobenthic phyla in the Great Kwa River, Nigeria, during the period of study (Pooled Results) (July – September, 2017)

	Station 1		**Station 2**	
Major macrobenthic phyla	n	%n	n	%n
Annelida	1	0.11	-	-
Mollusca (Bivalvia)	4	0.44	7	0.78
Mollusca (Gastropoda)	305	33.73	232	25.98
Palaemonidae	594	65.71	654	73.24
Total abundance (n)	895	99.99	893	100. 00

The station-by-station abundance of the macrobenthos is illustrated in Figure 3, while Figures 4a & b illustrate the relative abundance of the station-by-station distribution of the macrobenthos during the period of study.

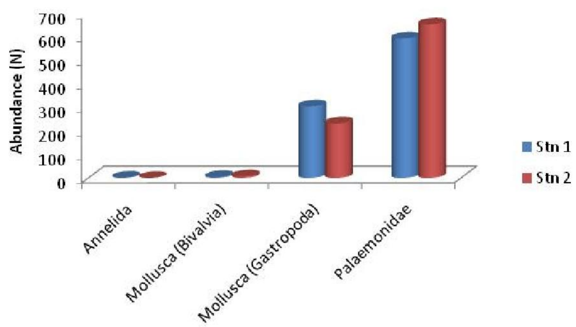

Fig. 3: Station-by-station abundance of the macrobenthic phyla, Great Kwa River, Nigeria, during the period of study (July – September, 2017).

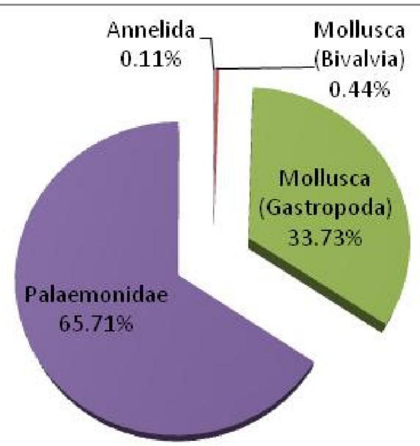

Fig. 4(a): Relative abundance of the major macrobenthos Station 1, Great Kwa River, Nigeria, during the period of study (July – September, 2017).

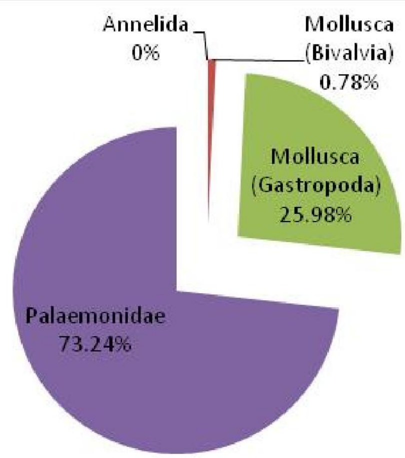

Fig. 4(b): Relative abundance of the major macrobenthos in Station 2, Great Kwa River, Nigeria, during the period of study (July – September, 2017).

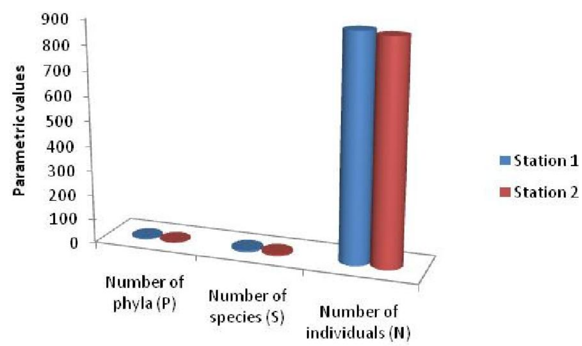

Fig. 5: Variations in the number of phyla, species and individuals of the macrobenthos at each of the sampled stations, Great Kwa River, Nigeria, during the period of study (July – September, 2017).

Table 4: Ecological indices of the macrobenthos in the Great kwa River, Nigeria. (July – September, 2017) (pooled Data)

Ecological parameters	**Station 1**	**Station 2**
Number of phyla (P)	4	3
Number of species (S)	7	6
Number of individuals (N)	895	882
Margalef's index (d)	0.882	0.737
Shannon-wiener index (H)	2.945	2.940
Simpson's index of dominance (D)	0.00052	0.00038

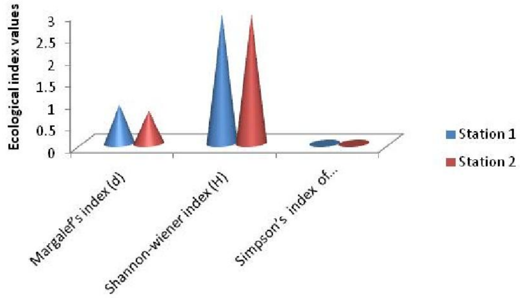

Fig. 6: Variations in ecological index value of the macrobenthos at each of the sampled stations, Great Kwa River, Nigeria, during the period of study (July – September, 2017).

4. Results and Discussion

The variations in the physico-chemical parameters during the period of study are presented in Table 1. Temperature ranged between 25.4 – 25.8^{0}C with a mean of 25.6 ± 2.28^{0}C at Station 1 in July, with a range between 25.4 – 25.9^{0}C with a mean of 25.6 ± 2.22^{0}C at Station 2, while in August, temperature ranged between Station 1, with a range of between 25.1 – 25.5^{0}C with a mean of 25.3 ± 2.24^{0}C at Station 2. In September, temperature ranged between 25.5 – 25.6^{0}C with a mean of 25.5 ± 2.25^{0}C at Station 1, and a range of 25.6 – 25.7^{0}C with a mean of 25.65 ± 2.25^{0}C at Station 2. pH during the period of study ranged between 5.64 – 5.66 with a mean of 6.65 ± 1.54 at Station 1 in July, 6.63 – 5.73 with a mean of 5.67 ± 1.54 at Station 2 and between 6.58 – 6.71 with a mean of 6.65 ± 1.54 in August at Station 1, 6.58 – 6.72 with a mean of 6.65 ± 1.54 at Station 2, while in September, pH ranged between 5.72 – 5.74 with a mean of 6.73 ± 1.55 at Station 1 and between 6.54 – 6.78 with a mean of 6.66 ± 1.54 at Station 2.

Dissolved oxygen (DOmgL^{-1}) ranged between 5.84 – 6.4mgL^{-1} with a mean of 6.16 ± 1.58mgL^{-1} in July at Station 1. At Station 2 dissolved oxygen maintained a fixed value of 5.0mgL^{-1} with a mean of 5.0 ± 0.0mgL^{-1} in July and August at both Stations, while in September, a DO range of between 5.4 – 5.6mgL^{-1} with a mean of 5.5 – 1.53mgL^{-1} was recorded at Station 1, and a range of 5.0 - 5.4^{0}C with a mean of 5.2 ± 1.51mgL^{-1} at Station 2. Salinity was not detected in the river water throughout the period of study.

The results of the study revealed a range of physico-chemical parameters that can support primary production of the Great Kwa River. None of the stations had temperature range less than 25.0^{0}C, pH range was also observed not to be less than 6.0. Again, dissolved oxygen fell within the permissible limit of 3 – 7mgL^{-1} concentration, with salinity maintaining a value of 0%000. These ranges are known to enhance biological productivity of water bodies (WHO, 2003; FEPA, 1971). Freshwater habitats are defined as having salinities of less than 1ppt (parts per thousand) or 1gram of total dissolved solids per litre of water (Alagoa and Wokoma, 2017). Zero salinity is therefore indicative of a typical freshwater condition which encourages freshwater macrobenthos to grow, reproduce and become recruited into the standing stock of the macrobenthos population (Job *et al.,* 2017).

The macrobenthic species recorded in this study agrees with those of George *et al.* 2010) from Okpoka Creek, Niger Delta, Nigeria, Nwoji*et al.* (2010), from a coastal lagoon, Lagos, Nigeria, Job and Ekpo (2017) from the Calabar River System, Nigeria, Ezekiel *et al.* (2011) from Sombreiro River, Niger Delta, Nigeria, Uwadiac (2010) from Epe Lagoon, South-West Nigeria.

pH being one of the most important water quality parameters has been found to have profound effects on the ecology of macroinvertebrates in aquatic system. Although benthic macroinvertebrate sensitivities to pH vary (Yuan, 2004), values below 5.0 and greater than 9.0 are considered harmful. Low pH values are associated with lower diversity of benthicmacroinvertebrates (Thompson and Friberg, 2002) and cause decreased emergence rates in them (Hall *et al.,* 1980). In macroinvertebrates low pH has been associated with egg failure (Willoughby and Mappin, 1988) and physiological problems because it is difficult for benthic macroinvertebrates to regulate ions within their bodies and to absorb the calcium needed for exoskeleton (Hall *et al.,* 1980). A decrease pH can trigger the release of heavy metals, which are toxic to benthic macroinvertebrates (Ramsey and Brannon, 1988).

Temperature is also one of the most important ecological factors which is intimately related to latitude, altitude and season (Hussain and Pandit, 2012). Macrobenthic fauna have evolved to live within a specific temperature ranges, which limits their distribution and affects the community structure (Hynes, 1960; Biggs *et al.* 1990; Hussain & Pandit, 2012). Temperature affects their emergence patterns, growth rates (Sweeney & Schnack, 1977), metabolism (Angeleer, 2003), reproduction (Vannote & Sweeney, 1980) and body size (Sweeney & Schnack, 1977).

Macrobenthos vary in their tolerance to temperature ranges, but few are able to tolerate temperatures beyond their upper tolerance limit (Coutant, 1962; Angelier, 2003; Hussain & Pandit, 2012). In this study, the ranges of the temperature which were within the tolerance limits are considered suitable for the wellbeing of the macrobenthos in the Great Kwa River.

The distribution of the macrobenthos was generally low. This might have been as a result of short period of sampling (3 months). Again, the near to absence of the Annelida (*Oligochaetes*) in the samples may indicate less pollution impact of that section of the Great Kwa River. The abundance of Annelida in the macrobenthos has generally been attributed to pollution (Edokpayi & Nkwoji, 2007; Umeozor, 1995; Hart & Zabbey, 2005; Eretemeijer & Swennen, 1990; George *et al.,* 2010; Ezekiel *et al.,* 2011).

Each of the macrobenthos showed differential station-by-station abundance. Similar observation was made by other authors in other aquatic system and attributed it to ecological differences of the different habitat locations and period of investigation, water quality, immediate substrate for occupation and food availability (Dance & Hynes, 1980; Ezekiel *et al.,* 2011; Claudiu *et al.,* 1979; Nkwoji *et al.,* 2010).

The gastropoda was the second most abundant macrobenthos at all the station while the Palaemonidae ranked number one in abundance. Typical among the gastropod molluscs were *Nerita apron* and *Tympanostonus fuscatus.* Nkwoji *et al.* (2010) reported the abundance of *T. fuscatus* in their macrobenthos of a coastal lagoon in Lagos, Nigeria, while *N. afra* was absent in their samples. Ezekiel *et al.* (2011) also report the presence of *T. fuslatus* in their samples from Sombreiro River, Niger Delta, Nigeria, with the absence of *N. afra.* Hart (1979), Job *et al.* (2017) and Job & Ekpo (2017), report respectively that studies conducted in different environment with different ecological settings, are likely to produce differential results even when the environment where the studies are conducted are within the same geographical region, tropical or temperate.

Also some macrobenthos which are non-sessile may be difficult to catch thereby showing low abundance in the sample (Job and Ekpo, 2017). This can be seen in the result of this study when the fiddler crab *Cardisoma armatum* showed less abundance. Similar observation was made by Hart (1979) in the macrobenthos of Bonny Mangrove Swamp, Niger Delta, Nigeria.

The high number of *Macrobranchium vollenhruenii, M. macrobranchion* and *M. equidens* may be attributed to the all-year-round presence of these species in the macrobenthos of the Great Kwa River. An all-year-round presence of the gastropod mollusc *Nerita afra* and *Pachymalania aurita* may be as a result of the favourable ecological conditions of the Great Kwa River, when relating it to values of the physico-chemical parameters during the period of investigation which were observed to generally fall within ranges capable of supporting biological processes in the river system.

Total of 1(0.11%) Annelida was recorded at Station 1, with no record of the macrobenthos at Station 2. At Station 1, 4(0.44%) of Bivalve molluscs were recorded with 7(0.78%) at Station 2, while at Station 1, 305 Gastropod molluscs were recorded which represent 33.73% of the total macrobenthos recorded at Station 1, with 232(25.98%) recorded at Station 2. Palaemonidae (Crustacea) had 594(65.71%) individuals at Station 1, with 654(73.24%) at Station 2 (Table 3).

The diversity of the macrobenthos was generally low, suggesting that the Great Kwa River might have been under pollution threat during the period of investigation. The diversity of the macrobenthos estimated by Margalef's index and Shannon-wiener index showed that Station 1 had Margalef's index of 1.028 with 0.883 for Station 2, while Shannon-wiener index of 2.948 was calculated for Station 1 with a value of 2.944 for Station 2. Edokpaye and Nkwoji (2007) reported low diversity index for the macrobenthos in the Lagos Lagoon, Nigeria and related it to pollution. Low Shannon-wiener index was also reported by Nkwoji*et al.* (2010) for the macrobenthos in a South-Western Lagoon, Lagos, Nigeria, and attributed it to pollution of the Lagoon. Similar observation was made by Ezekiel *et al.* (2011) for the macrobenthos in Sombreiro River, Niger Delta, Nigeria.

The ecological indices of the macrobenthos of the Great Kwa River, Nigeria are presented in the Table 4. At station 1, 4 macrobenthic phyla were recorded with 3 phyla at station 2, while total of 895 individual macrobenthos were recorded at station 1 with 882 individuals at station 2.

Margalef's index (d) was 0.882 at station 1 with an index of 0.737 at station 2, while Shannon-wiener index (H) was 2.945 at station 1, with an index of 2.940 at station 2.

Simpson's index of dominance (D) was 0.00052 at station 1 with an index of 0.00038 at station 2.

The variations in the number of phyla, species and individuals of the macrobenthos at each of the stations are depicted in Figure 5, with Figure 6 illustrating the variations in the Margalef's, Shannon-wiener and Simpson's dominance indices of the macrobenthos during the period of study.

Ali *et al.* (2003) report that diversity index ranging between 1 – 3, indicate moderate pollution of the system, while value less than 1 indicate heavily polluted system and values greater than 3 windows clean environments.

5. Conclusion

Investigations were conducted on the influence of physico-chemical parameters on the biodiversity and distribution of macro-invertebrates along the

Great Kwa River, Nigeria. Results revealed that there were variations in the physico-chemical parameters during the period of study. Temperature ranged between 25.4 – 25.8^{0}C with a mean of 25.6 ± 2.28^{0}C at Station 1 in July, with a range between 25.4 – 25.9^{0}C with a mean of 25.6 ± 2.22^{0}C at Station 2, while in August, temperature ranged between Station 1, with a range of between 25.1 – 25.5^{0}C with a mean of 25.3 ± 2.24^{0}C at Station 2. In September, temperature ranged between 25.5 – 25.6^{0}C with a mean of 25.5 ± 2.25^{0}C at Station 1, and a range of 25.6 – 25.7^{0}C with a mean of 25.65 ± 2.25^{0}C at Station 2. pH ranged between 5.64 – 5.66 with a mean of 6.65 ± 1.54 at Station 1 in July, 6.63 – 5.73 with a mean of 5.67 ± 1.54 at Station 2 and between 6.58 – 6.71 with a mean of 6.65 ± 1.54 in August at Station 1, 6.58 – 6.72 with a mean of 6.65 ± 1.54 at Station 2, while in September, pH ranged between 5.72 – 5.74 with a mean of 6.73 ± 1.55 at Station 1 and between 6.54 – 6.78 with a mean of 6.66 ± 1.54 at Station 2.

Dissolved oxygen (DOmgL^{-1}) ranged between 5.84 – 6.4mgL^{-1} with a mean of 6.16 ± 1.58mgL^{-1} in July at Station 1. At Station 2 dissolved oxygen maintained a fixed value of 5.0mgL^{-1} with a mean of 5.0 ± 0.0mgL^{-1} in July and August at both Stations, while in September, a DO range of between 5.4 – 5.6mgL^{-1} with a mean of 5.5 – 1.53mgL^{-1} was recorded at Station 1, and a range of 5.0 - 5.4^{0}C with a mean of 5.2 ± 1.51mgL^{-1} at Station 2. Salinity was not detected in the river water throughout the period of study.

The species composition of the macrobenthos identified during the period of study consisted of 8 macrobenthos belonging to 4 macrobenthic groups were identified. These were Annelida (*Oligochaeta*) (*Glycera convoluta*), Mollusca (Bivalvia) (*Egeria paradoxa*), Mollusca (Gastropoda) (*Nerita afra* and *Pachymelania aurita*), Palaemonidae (Crustacea) (*Cardisoma armatum*, *Macrobranchium vollenhovenii, M. Macrobranchion* and *M. equidens*. Higher number of macrobenthos were sampled at Stations and Months of high dissolved oxygen, low temperature and slightly acidic content.

Ecological indices of the macrobenthos of the Great Kwa River, Nigeria in the present study were also observed to vary at each station. At station 1, 4 macrobenthic phyla were recorded with 3 phyla at station 2, while total of 895 individual macrobenthos were recorded at station 1 with 882 individuals at station 2. Margalef's index (d) was 0.882 at station 1 with an index of 0.737 at station 2, while Shannon-wiener index (H) was 2.945 at station 1, with an index of 2.940 at station 2. Simpson's index of dominance (D) was 0.00052 at station 1 with an index of 0.00038 at station 2.

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