

**EVALUATION OF FISH BIODIVERSITY AND YIELD POTENTIALS OF  
CHALLAWA LAKE, KANO STATE NIGERIA,**

**BY**

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## **DECLARATION**

I hereby declare that this work is the product of my research efforts undertaken under the supervision of Dr. Idris Ado Yola and has not been presented anywhere for the award of a degree or certificate. All sources have been duly acknowledged

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**CERTIFICATION**

This is to certify that the research work for this dissertation and the subsequent write-up (NAZEEF SULEIMAN SPS/15/MZO/00006) were carried out under my supervision.

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This research work is dedicated to my daughter Amatulahaman Nazeef Suleiman, my wife Ummulkhairi Mahdi Doho, my father Alhaji Suleiman Muhammad Kalah and my mother Hajiya Sa'adatu Yakubu.

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## ABSTRACT

Fish species compositions of the three sites of Challawa dam were studied over a six months period (March to August, 2017) and revealed ten (10) species belonging to nine (9) families with mormyrids being the dominant species. The condition of fish species identified showed a 50-50 ratio of below and average condition of fish. Reservoir morpho-metrics and ionic input of dam were applied to estimate the potential fish yield using morpho-edaphic index (MEI). The potential fish yield estimates of the three sites are 88.05, 98.56 and 111.12 Kg/ha. The anglers were 53.3, 65.7 and 57.05 Kg respectively, which implied that the relative yield indices were 44.5%, 49.9% and 38.5%. The results of this study showed that, the reservoir's exploitation level was moderate ( $RYI \leq 1$ ). Good ionic content, good dissolved oxygen levels, good pH, low-levels of pollution, accounted for the high estimates of the fish yield. Therefore effective management system, implementation of good fishing regulations and practices is being implemented and should be sustained.

## **CHAPTER ONE**

### **1.0**

### **INTRODUCTION**

Fish is an inexpensive source of protein and an important cash crop in many regions of the world (Bhatnagar & Devi, 2013); hence natural lakes are important resources throughout West Africa and contribute substantial economic benefits to people through fishing, water transport, swimming, and other recreational uses. The components of commercial and subsistence fisheries are among the most important, social and economic values of natural lakes. Therefore, fisheries managers of natural lakes must balance demands for fishing with demands for boating, swimming, or other uses, which requires managers to be skilled in fishery science, resource economics, and public policy (Krueger, 2010).

Shallow reservoirs are numerous in Tropical Africa, but the study of their limnology and fisheries potentials are scanty despite their high potentials for fish production as compared with temperate reservoirs (Mustapha, 2009).

Fish is a high quality food and its protein content is high; it is rich in vitamins and contains variable quantities of fats and calcium for human health (Ja'afaru & Abubakar, 2015). Inland fisheries are extremely diverse and harvest a tremendous amount of biodiversity. Inland fishes in Nigeria is said to contribute about 200,000 metric tons to the total annual National fish production that stagnates at about 500,000 metric tons. Nigeria consumes some 1.3 million metric tons of fish a year including up to 700, 000 metric tons of imported frozen fish (Miller, 2004)

Nigeria is blessed with abundant natural water bodies with abundant fish resources. Nigerian freshwater bodies are the richest in West Africa in terms of fish abundance and the fish resources (Lawson, 2010). Apart from being a major source of high quality animal protein for man,

provide several socio-economic values as sources of job opportunities and raw material for some fish industrial activities as well as recreational purposes (Abubakar & Nazeef, 2013).

An estimation of the species composition is important to the study of a stock's dynamics and in the management of species. Densities indices of stocks are often used in stock assessment in multi-species assessment, ecosystem studies and in studies of economically and environmentally important fish species. It is often necessary to know the absolute size of the stock (Ahmad *et al.*, 2014).

The importance of understanding fish production in natural lakes is obvious. Fisheries management deals with “two really different issues: what nature can produce, and what we can do to manage the activities of those who would capture that production (Chow-fraser, 1991). The fishery potential of a lake depends on its productivity, that is, the ability of any trophic level to produce biomass. Because lower trophic levels are the food base of higher trophic levels, productivity at different levels tends to be positively correlated. Therefore, productivity of a fish assemblage is constrained by factors that limit primary production in any ecosystem, including natural lakes (Laë *et al.*, 1999)

The Morpho-Edaphic Index (MEI) has been used globally as a fish-yield estimator with widely divergent result (Ryder, 1982). The fundamental Concept of the MEI embraces standard thermodynamic theory, that of matter (nutrients) transported by energy within an open system. Fish yield is a biotic output of the system. Constraints on the level of fish yield are determined by lake-basin morphometry, nutrient and energy availability. The three morphometric factors considered; mean depth, volume, and area, mean depth appears to be the variable most closely linked with production process (Ryder, 1982).

Several limnological parameters such as conductivity, total dissolved solids, Phytoplankton and reservoir morphometry have been used in estimating potential fish yields from reservoirs. The most widely accepted method was the Morpho-Edaphic Index (MEI) developed by Ryder (1965) cited in (Mustapha, 2009).

The Morpho-Edaphic Index (MEI), evaluated as the concentration of total dissolved solids (TDS) divided by mean depth, is commonly used by fisheries biologists to predict potential fish yield in lakes (Chow-fraser, 1991). The conceptual framework and assumptions underlying the model were later described (Ryder *et al.*, 1974; Ryder 1982). The assumptions are; bedrock geology largely determines the concentration of TDS entering lakes, TDS is a surrogate for essential nutrients, such as phosphorus and nitrates, that control lake productivity, and mean depth is a surrogate for hydrological characteristics such as thermal stratification, nutrient circulation, and dilution, all of which affect how energy is processed within the water column (Hansen, Nigel, & Krueger, 2010).

The Challawa gorge dam is situated with seven surrounding settlements; this makes it possible for fishing activities and irrigation on the dam. The low depth of the dam is suitable for the application of Morpho Edaphic Index for fish biomass assessment and diversity evaluation. Three prominent and easily accessible study sites (Feginma, Sakarma and Turawa) were selected to give a general overview of dam where there are much fishing activities.

### **1.1 Aims of the Research**

The aim of the research is to study the fish biodiversity and potential yield of Challawa Lake; Kano State, Nigeria.

### **1.2 Objectives of the Study**

The research objectives are;-

1. To determine the physical and chemical parameters of the Lake viz: pH, temperature, TDS, dissolved oxygen, nitrates, phosphates and Depth.
2. To identify fish species and evaluate condition factor (K) of representative fish species identified in the Lake.
3. Assessment of Morpho-Edaphic Index of the Lake water.

### **1.3 Justification**

This study is to determine the natural fish species diversity, their abundance and “wellbeing”, and the fish productivity of the natural aquatic ecosystem and its exploitation level(s) as tools in rational management of the fisheries.

### **1.4 Research Hypothesis**

In this research, the study null hypotheses states that:

- Challawa gorge dam water body has less diverse fish species.
- The Physico chemical parameters are above the tolerance limit for fish

## CHAPTER TWO

### 2.0

### LITERATURE REVIEW

#### 2.1 Reservoir as Fish Habitat

Water is mostly conserved in reservoirs, lakes, ponds, dams, paddocks, pools, inundations and other impoundments. Reservoirs are the best method of impounded water; because it ensures that water is available all the year round and helps in minimizing abstraction from rivers (Mustapha, 2009), aquatic lives including fish depend on water in these impoundments in which the quality of such water influences feeding, growth, disease burdens, and survival rates of such aquatic lives (Sriyasak *et al.*, 2015).

#### 2.2 Fish

A fish refers to the numerous cold-blooded aquatic vertebrates characteristically having fins, gills, and a streamlined body and including the bony fishes, such as catfishes and tunas, and the cartilaginous fishes such as sharks and rays (Google.com, 2017), hence the former has the most diverse group and represented in the freshwater, while the latter are predominantly marine occurring at different depths of salt waters (Leveque *et al.*, 2007).

About 25,000 species of fish have been described, this is the most numerous group of vertebrates approximately 45-50% of all vertebrate species are fish and are the dominant life form in almost all aquatic systems with many diverse adaptations to life and very interesting group for biologists, the potential of many species as a food source, a valuable resource worth studying for knowledge of management and harvest strategies. However, the exact number of existing fish species is yet to be determined, despite the 28,900 species cited by FishBase in 2005, some experts still feel that there's a need to look further as the number may be higher of which 34% of these species are confined to Exclusive Economic Zone (EEZ) while approximately 44% are

freshwater fisheries inhabiting water of very low salinity (below 1 part per thousand or conductivity of 1000 $\mu$ s/cm).

### **2.3 Fish Biodiversity**

Fish biodiversity is often ambiguously misused or overused to describe population dynamics of a location or a community. It is simply a measure of the number of fish species that constitute a biologic aquatic community, which is considered to be one of the most important aspects of community organization and structure (Lawson & Olusanya, 2010). Fish species richness and relative abundance describe key elements of biodiversity (Nazeef & Abubakar, 2013).

The fish diversity which is currently recognized worldwide shows 25,000 species, of which 10,000 species are found in freshwater ecosystems. Specialists have estimated that at least 5,000 await discovery. Fish exhibits the greatest biodiversity among the vertebrates, with approximately 25,000 species, comprising about known vertebrate species (Ghaffar, 2008). An updated review of Nigerian fish fauna reveals that there are about 21 families of fish species distributed in different water bodies (Ita, 1993). However of these species; 34% are restricted to the Exclusive Economic Zone (EEZ) while approximately 44% are freshwater fishes inhabiting water bodies of low salinity (Lawson & Olusanya, 2010) out of this, the artisanal fisheries sector supplies about 90% of domestic fish need in Nigeria, with the balance coming from the industrial sector, largely regarded as fish imports (Oruonye, 2014). Thus freshwater fish discovery can serve as a platform of livelihood and biodiversity of conservation values ([www.fishbase.org](http://www.fishbase.org), 2009)

The natural aquatic systems have witnessed changes in stock diversity and abundance, genetic structure and age composition of stocks resulting from structural changes in habitat, food composition and uncontrolled exploitation (Omowumi, 2013), Fisheries resources are fast

reducing in Nigeria due to over exploitation and inadequate management of her inland waters. An adequate knowledge of species composition, relative abundance of her water bodies must be understood and actively pursued for the sustainability of these resources (Ayamre & Ekelemu, 2016),

Fishing practice is attracting a lot of focus because it contributes significantly to the world proteins requirement. Hence Nigeria's populations live near water bodies such as lakes, lagoons, reservoirs, rivers, swamps and coastal lagoons. Many depend heavily on the resources of such water bodies for their main source of animal protein and family income (Nazeef & Abubakar, 2013). Inland fisheries provide food and employment in rural areas where few other options are available. Over 60 million people in developing countries are involved in aspects of small-scale inland fishing. A large quantity of the marine catches is reduced to fishmeal or oil used to raise farmed fish (Ja'afaru & Abubakar, 2015). According to Darwall and Vie (2005), freshwater fishes are one of the most endangered taxonomic groups due to their high sensitivity to quantitative and qualitative alterations of aquatic habitats, as a consequence; they are often used as bioindicators for the assessment of water quality, flow regime, river network and connectivity (kang *et al*, 2009). The management of fish biodiversity and associated habitats is a huge task (Abubakar & Nazeef, 2013). Hence, conservation measures to mitigate the impact of pressures have greatly been slow and inadequate and as a consequence many fish species are declining rapidly (Wazir, 2010). In Nigeria, freshwater resources are on the decline due to over exploitation and inadequate management of inland aquatic water bodies (Lawson and Olusanya, 2010).

An estimation of the species composition is important to the study of a stock's dynamics and in the management of species. Densities indices of stocks are often used in stock assessment in

multi-species assessment, ecosystem studies and in studies of economically and environmentally important fish species (Ahmad *et al.*, 2014), thus, there is a strong need to develop low cost methods for estimation of absolute fish numbers (Auvnen & Juha, 1994). Fisheries stock assessment is primarily used for some decision making process, and as the process becomes more quantitative, the demand for stock assessment will increase (Hilborn *et al.*, 1994.)

The pioneering fishery resource survey of Lake Alau in Maiduguri, Borno State carried out by Odunze (1995) revealed ten (10) species representing seven (7) families, Ita (1993) reported 268 different species in 34 different well known freshwater rivers, lakes, reservoirs, which constitute about 12% of Nigeria's surface area. Kogi State in this case is blessed with natural and man-made water bodies which include Gbedike Lake which is one of the largest known natural Lake in the state. Most of the valuable fish stock in the water bodies are already fully exploited and relatively new stock are unveiled to exploitation (Bankole and Mbagwu, 1995). Abubakar and Ja'afar (2015) identified 26 species representing 14 families in Dadin-kowa dam. Also 15 species were identified representing 11 families from the same dam by Nazeef and Abubakar (2013). Eight (8) families were identified from three lakes (Ajiwa, Zobe and Jibya) in Katsina State (Ahmad *et al.*, 2014). A survey of the artisanal fisheries of Kontagora Reservoir was conducted, using statistical frame survey and catch assessment survey; the survey revealed five (5) fish families made up seven fish species (Ibrahim, Auta, & Balogun, 2009)

### **2.4.1 Fish Species Assemblage Structure**

### **2.4.2 Species Diversity Indices**

Richness (S): richness is the total number of species in a community. It is the most simple biodiversity index and it does not take into account any characteristic of species or their relative abundance. Several estimators to avoid bias due to unseen or unrecorded species are currently used to estimate species richness (Magurran, 2004). In a functional diversity context, it is common practice to include enough species to account for near 80% of the abundance. This approach does not need to adjust observed species, number because functional diversity is not affected by rare species (Casanoves, Alejandro, & Rienzo, 2012).

Shannon Index (H): this index assumes that heterogeneity depends on both, the number of species in a community and their proportional abundances. Conceptually, it is a measure of uncertainty degree related to a random selection of individuals from the community. In a homogeneous community with S species, in which only one is dominant (highly abundant), the uncertainty degree of selecting a given species is lower than if all species would have the same abundance. When species abundances are uneven, the probability that a random individual taken from the population belongs to the dominant species approximates one; conversely, in a heterogeneous community any randomly drawn individual has the same probability ( $1/S$ ) to belong to any species. The Shannon index is one of the biodiversity measures most widely used. The Shannon index assumes that individuals are randomly sampled from an “indefinitely large” (i.e., an effectively infinite) population. The index also assumes that all species are represented in the sample (Shannon and Weaver, 1949).

Simpson Index (D): Simpson index of biodiversity equals the probability of drawing without replacement two individuals of different species from a given collection. There is more than one form to express the index. The expression widely used offers the index as a measure of dominance (Casanoves *et al.*, 2012).

The number of fish species present in natural aquatic ecosystem (species richness) increases with lake size, presumably because lake size is correlated to habitat diversity (Kalff 2002). Species richness in natural lakes is also affected by physical (latitude and altitude) and chemical (such as TDS, pH, conductivity) attributes of individual lakes (Hansen *et al.*, 2010). Native species occupying any lake were derived by a process of “hierarchical filters” operating at sequentially lower spatial scales, including continental, regional, lake type, and local scales (Tonn, 1990). Consequently, the particular assemblage of fishes occurring naturally in any lake is a consequence of the fish fauna with access to the lake, either during lake formation or through connectedness to other rivers and lakes that can live in the habitat present in the lake (e.g., tolerance to ambient temperature; (Tonn, 1990).

## **2.5 Fisheries of Inland Water Bodies**

Inland fisheries are extremely diverse and have a tremendous amount of biodiversity (Miller, 2004). The Nigeria’s inland water fisheries is said to have been estimated at over 14million hectares that are being fished predominantly by artisanal fishermen (Omorinkoba *et al*, 2011) which contribute to about 50% of the animal protein intake of the country’s population especially the resource poor in Nigeria and local production has been estimated at about 700,000 metric tons (Ahmed and Yusuf, 2014). Apart from protein supply; inland fisheries serves as a major sources of livelihood, providing direct and indirect employment to over 200 million people of the world, majority of who live in developing world (Daw *et al.*, 2009).

## **2.6 Fish Species Resources Sustainability**

Inland fishery is an important aspect of Nigeria's fisheries economy as it contributes to about 40% of the total fish supply in Nigeria (FDF, 2003). The over exploitation of the limited resources has resulted in a sharp decline in Inland rivers and lakes fish production (Eyo & Ahmed, 2000) due to the over 160 million people of the country would demand about 3.32 million metric tons (Jim-Saiki, 2014), the fisheries of major inland water bodies have been identified with special emphasis on potentially endangered species. The issue pertaining to the rational management and conservation of this important fisheries sector for sustainability has only been highlighted. Economic activities have been unregulated and therefore haphazard with adverse consequences on the Ichthyofauna especially the biological important endemic species (FDF, 2003).

Indigenous and traditional method in resource sustainability such as water tenure, ritual prohibitions, taboos, and magic as well as gear restriction, closed seasons and flood plain intensification management strategies are common practices in Nigeria. However, these practices have little or no legal framework and so could not be effectively enforced (Obasohan, 2006).

Fisheries management is important to retain the sustainability of the fisheries resources. Information gathered, analyzed and interpreted can be used to make informed decisions about the state of the fisheries and environment. This is used to plan and strategize on management measures to adopt.

## **2.7 Fish Condition Factor**

The condition factor (K) as applicable to fish growth pattern is the condition of general wellbeing of fish as well as an indicator of physiological state of the fish in relation to its welfare and also provides information when comparing two populations living in certain feeding density,

climate and other conditions. Hence, the condition factor  $K$  value is calculated from the weight and length, and can be used to estimate changes in nutritional condition (Jin *et al.*, 2015); studying, understanding the life cycle of fish species and it contributes to adequate management of these species, hence, maintaining the equilibrium in the ecosystem (Lizama, 2002, Oyewo, 2015).

Condition factor is affected heavily by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live (Abubakar and Nazeef, 2013). Condition factors of different tropical fish species were investigated and reported by (Saliu, 2001, Lizama *et al.*, 2002, Nazeef, 2013, and Oyewo, 2015).

Age of fish, sex, season, stage of maturation, fullness of gut, type of food consumed, amount of fat reserve and degree of muscular development all are biotic and abiotic factors that influence the value of “ $K$ ”. However, the value of “ $K$ ” is not fixed initially in the life span of all species; in some species like female trout the gonads at maturity may weigh up to 15% of the total body weight which maybe shed out during spawning and affects the value of “ $K$ ” of the fish (Charles & Alan, 1998).

Andem *et al.*,(2013), illustrated that the value of “ $K$ ” is not constant for individuals; species, populations, but is subject to wide range of variations for fish of an average natural conditions. The  $K$ -factor should be equal to 1, while  $<1$  and  $>1$  indicate below and average conditions respectively. Wade (1992) stated that condition factor greater or equal to one is good.

### **2.8.0 Physico-Chemical parameters of inland water**

The study of the Physico-chemical properties of water is a fundamental part of limnology and has diverse usage to the assessment of water quality, biological productivity and trophic status, as well as composition, distribution and abundance of biotic organisms (Mustapha, 2009).

The quality of water parameters such dissolved oxygen (DO); pH, phosphates, salinity and nitrates influence the healthy growth as well as the survival of fish and other integral components such as algae, shrimps, and crayfish of both fresh and marine aquatic habitats. The productivity of a given body of water is determined by its physical, chemical and biological properties; therefore these parameters have to be monitored for the survival of fish (Olurin, 2006).

#### **2.8.1 Temperature**

Dependent upon geomorphic conditions and local climate; temperature is a fundamental factor that influences the distribution of aquatic organisms. Water temperature comes from solar radiation by direct absorption. Many biological processes in water are triggered by temperature. Preference to temperature varies among species but all species can tolerate slow seasonal changes better than rapid changes. For example, between 20 – 25°C, diatoms, predominate and green algae at 35°C (Berman & Steinman, 1998). Temperature can influence zooplankton production directly via physiological process as zooplankton metabolism is highly temperature-dependent in addition to the indirect effect via primary production (Bottrell *et al.*, 1976). Temperature also influences fish by controlling reproductive cycles, feeding and metabolic rates, swimming performance, growth rates and distribution (Countant, 1975). It also plays an impact on the dominance and distribution of phytoplankton in water as it influences the growth rate and mortality of zooplankton and other organisms (Oyewo, 2015). Temperature influences other factors such as the existence of direct relationship between temperature and dissolved oxygen also exists. As

temperature increases, dissolved oxygen decreases and may affect organisms to varying degrees, depending on their sensitivity (Mustapha, 2009).

Martinez-Placious *et al.*, (1993) suggested that the temperature range of 20°C to 30°C for fish is good, while the lethal levels are from less than 2°C and higher than 42°C for tropical fishes but cold water fishes can survive a temperature range of 5°C-15°C.

### **2.8.2 Transparency**

Light is a vital component to the existence of aquatic lives as it plays an important role to the metabolism of fresh water ecosystem (Wetzel, 2001), as it guides primary productivity. Attenuation of light influences a reservoir's thermal regime, taxonomic composition, distribution and production of macrophytes, phytoplankton, zooplankton and fishes. Transparency in water is a function of light penetration (Mustapha, 2009). Wetzel (1999) revealed that secchi disc transparencies range from a few centimeters to 10 meters in reservoirs, lakes and dams. Fresh water transparency is strongly influenced by the growth of blooms of phytoplankton, explosiveness of macrophytes and large inorganic suspended materials, which reduce light penetration into the water body, consequently reducing depth of the euphotic zone, and primary production which in turn reduces food supply and availability to fish, thereby leading to retardation of secondary productivity (U.S.E.P.A, 1976).

Variations occur in secchi disc transparency with rainfall in freshwater habitat (Biswas, 1978), while Egborge (1971) observed a high positive correlation between transparency and conductivity.

### **2.8.3 Dissolved oxygen**

Dissolved oxygen defines the level of free, non-compound oxygen present in water body or other fluids. It is however, an important parameter used in the assessment of water quality because of its impact on aquatic organisms living within the water body. In accordance to limnology; dissolved oxygen is an essential factor second to the water itself (Wetzel, 2001).

Dissolved oxygen is virtually an integral component to life in aquatic environment as it affects the physiology and distribution of the aquatic organisms. Nearly all aquatic organisms, with the

exception of some bacteria, must have oxygen to survive and most of these organisms must extract their oxygen from water. The two main sources of oxygen into the aquatic environment are the atmosphere and photosynthetic activities of aquatic plants. The ideal range of dissolved oxygen in water which must be at least 6mg/l is required to sustain fish and other aquatic life, despite this range of oxygen, there's exist a variation for the demand of oxygen from creature to creature as well as species to species. For instance bottom feeders, crabs, oysters and worms require a minimal amounts of oxygen (6-13 mg/L) while shallow water fish need higher levels (6-15) mg/L (EPA, 2013). Insufficient dissolved oxygen (DO) in a water system causes/results in anaerobic decomposition of organic material thereby leading to the production of obnoxious gases such as carbon dioxide, hydrogen sulphide and methane which bubble to the surface, these may result into hypoxia, fish kill, winterkill, poisoning of water column, and depletion of available oxygen for fish and other aquatic organisms (Willis, 2006).

Dissolved oxygen (DO) is commonly measured to assess metabolism of aquatic ecosystems. However, concentrations of DO depend on many factors in addition to ecosystem metabolism, such as water temperature, gas exchange with the atmosphere, abiotic chemical reactions, inputs in precipitation, groundwater, surface water, pressure, salinity and water circulation (Langman *et al.*, 2010).

#### **2.8.4 Inland Water Salinity**

Salinity is a term with several non-specific definition(s), however as a basic definition; salinity refers to the all dissolved salts in water (Wetzel, 2001). Dissolved salts are basically electrolytes, these electrolytes form ionic particles as they dissolve with each a positive and negative charge, as such salinity is an attribute to conductivity and can be measured in percentages (Sommer, 2004).

A good number of different dissolved salts are attributed to the salinity of water, however the major ions present in inland lakes are alkali and alkaline earth metal salts such as calcium, magnesium, sodium, carbonates and chlorides building up a high percentage of the ionic composition hence, the

composition of inland water salts sources are dependent upon the surrounding environment (Paytan, 2006, Wetzel, 2001). Salinity and conductivity have strong correlations, as conductivity measurement is easier to assess, it is used in algorithms estimating salinity with TDS both of which affect water quality (Miller, 1988).

Salinity is very important to aquatic lives as it influences dissolved oxygen concentration and solubility, hence most aquatic organisms tolerate only a specific level of salinity (S.W.R.C.B, 2002), and that the physiological adaptation of each species is determined by the salinity of its environment (Webster, 2013).

Fluctuations in salinity levels of inland waters is an indication of pollution (EPA, 2012) due to excessive rainfall, drought regardless of human induced or nature has detrimental effects on aquatic lives.

Most aquatic species are adapted to a specific salinity levels, as such any salinity values beyond the normal can result in fish kill, due to the dynamics in dissolved oxygen concentrations, osmosis regulation and TDS toxicity (Scannell, 2001).

### **2.8.5 Inland water pH**

No chemical concept, dependent upon a mathematical twist has been received more enthusiastically by ecologists than pH (Talling, 2010), pH is a determined value based on defined scale, similar to temperature, this implies that pH of water is not a physical parameter that can be assessed as a concentration or in quantity, but rather it is a scale between 0 to 14 defining how acidic or basic a body of water is along a logarithmic scale (Webster, 2013). A pH value of 7 is said to be neutral and water is said to be pure at such pH value.

Fluctuations in pH levels do occur as a result of so many factors, both natural and man-made. However, most natural changes occur due to interactions with the surrounding rock (especially

carbonate forms) and other materials. It can fluctuate with rainfall (particularly acid rain), wastewater and mining discharges (EPA, 2012).

Natural elements that fluctuates pH levels includes carbonate materials and limestone, which have the ability to buffer pH changes in water. In addition to natural causes of pH changes; pH levels can fluctuate daily due to photosynthesis and respiration in the water. The degree of change depends on the alkalinity of the water. Carbon dioxide is the most common cause of acidity in water. Photosynthesis, respiration and decomposition all contribute to pH fluctuations due to their influences on CO<sub>2</sub> levels (Bialkowski, 2006).

Anthropogenic causes of pH fluctuations are usually related to pollution. Acid rain is one of the best known examples of human influence on the pH of water. Any form of precipitation with a pH level less than 5.0 is known as acid rain (Lenntech, 2013), additional sources of man-made influence on pH dynamics includes mining and smelting operations, fossil fuel combustion such as coal burning and automobiles (Utah, 2013), wastewater discharge that contains detergents and soap-based products can cause a water source to become too basic (Osmond *et al.*, 1995).

The recommended pH range for most fish is between 6.0 and 9.0 with a minimum alkalinity of 20 mg/L, with an ideal CaCO<sub>3</sub> levels between 75 and 200 mg/L (Wurts *et al.*, 1992). However, sensitive species of inland waters such as salmon prefer pH levels between 7.0 and 8.0, they become severely distressed and suffers physiological damage due to absorbed metals at levels below 6.0 (Chambers *et al.*, 2012), Whereas most inland water confinement(s) have pH levels of 6-8 depending on the surrounding soil and bedrock, hence the ideal pH levels for fish are 7-8 and fish blood has a pH value of 7.4 (Wurts *et al.*, 1992), most fish can adapt to the pH level of their environment (6.0-9.0) as long as there are no frequent fluctuations (Osmond *et al.*, 1995).

Detrimental effects of pH become noticeable when the pH of water falls below 5.0 or rise above 9.6. Negative impacts due to acidification are more pronounced in saltwater fish than freshwater fish, due to their adaptation to a higher pH. Also, when pH is below optimal levels, fish become susceptible to fungal infections and other physical damage, also as the pH of water falls, the solubility of calcium carbonate is reduced, inhibiting shell growth in aquatic organisms (Radke, 2006). In general, fish reproduction is affected at pH levels below 5.0 and many species such as sensitive inland water fish like *Tilapia zilli* will migrate from the source of contamination (Lenntech, 2013) and other fishes tend to die when pH falls below 4.0 (U.S.G.S., 2013).

### **2.8.6 Conductivity of Inland Water**

As defined by EPA (2012), conductivity refers to the measure of water's capability to pass electrical flow and is usually measured in micro or millisiemens per centimeter. This ability is directly related to the concentration of ions in the water. Conductive ions are sourced from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds (Miller *et al.*, 1988), this further suggests that compounds that dissolve into ions are also known as electrolytes (Pratt, 2013). Therefore, the higher the conductivity of water, the more ions that are present and vice versa.

Conductivity varies greatly between different bodies of water, however most freshwater lakes have low conductivity and salinity values in comparison to seawater which have high conductivity and salinity due to the high number of the dissolved salts present (EPA, 2012), this implies that in lakes, dams, streams and rivers, normal conductivity levels come from the surrounding geology. Clay soils will contribute to conductivity, while granite bedrock does not. The minerals in clay will ionize as they dissolve, while granite remains inert as weathering of the rock takes a longer time. Likewise, groundwater inflows will contribute to the conductivity of the

lakes, stream or river depending on the geology that the groundwater flows through. Groundwater that is heavily ionized from dissolved minerals will increase the conductivity of the water into which it flows (Perlman, 2014).

Conductivity and Total Dissolved Solids (TDS) are correlated. And as such measured conductivity or TDS values are used to estimate the potential yield of fish in shallow inland waters (Edward, 2013). This is due to the assumptions that (a) bedrock geology largely determines the concentration of TDS entering lakes; (b) TDS is a surrogate for essential nutrients, such as phosphorus, that control lake productivity (Chow-fraser, 1991).

Conductivity values has been applied by many researchers to assess the potential yield of fish which includes (Edward, 2013; M. K. Mustapha, 2009; Perera, 2003; Quarcoopome & Amevenku, 2008)

### **2.8.7 Total Dissolved Solids (TDS)**

Total dissolved solids (TDS), refers to the combined sum of all ion particles that are smaller than 2 microns (0.0002 cm) in natural waters (EPA, 2012) and are closely related to the specific conductance of the water (Mustapha, 2009). This includes all of the disassociated electrolytes that built up salinity concentrations, as well as other compounds such as dissolved organic matter are a measure of the total concentration of dissolved substances (ions) (Thompson, 2006).

In “clean” water, TDS is approximately equal to salinity (Thompson, 2006). There exist a correlation between TDS and conductivity and hence, the former is measured in mg/L in which the EPA, USPHS and AWWA recommend an upper limit of 500 mg/L TDS, though this is exceeded in some regions with little ill effect (Paytan, 2006).

Ponce (2014), stated that inland water at most can have 2000 mg/L of total dissolved solids, and most sources should have much less than that, with regards to the sources of the ionic properties, excessive total dissolved solids can produce toxic effects on fish and fish eggs. Large quantity of TDS can render freshwater not suitable for domestic and industrial use, as well as, High TDS in drinking water can cause an unpleasant taste, hardness, colored water, stains, and salty taste and may render the water unsuitable for irrigation practices (Mustapha, 2009). However, TDS of less than 500ppm is desirable in drinking water (Moore, 1989). TDS has been used to assess potential yield of fish production in lakes and reservoirs. Ryder (1965) developed the Morpho edaphic index (MEI) with diverse applications, and as the ratio of total dissolved solids to mean depth to calculate the potential fish yield in lakes, whereas, Reiger *et al.* (1971), Henderson and Welcomme, (1974) and Adeniji (1991) have all applied this method in African lakes and reservoirs.

#### **2.8.8 Nitrates of Inland Water**

The amount of dissolved salts in water is of major importance to the maintenance of aquatic life and nitrate is one of the inorganic salts which dissolves in water (Enderlein & Peter, 1996). Nitrate is the dominant form of nitrogen (Ville, 2011), which stimulates algal growth, (Mustapha, 2009). Nitrate is commonly found in freshwaters arising from rainfall, fertilizer runoff from farm, raw sewage entering the water and inputs from land surface. High concentration of nitrate in water leads to eutrophication and this can degrade water quality by encouraging excessive growth of algae (Dodds & Smith, 2016), which the aftermath of this growth lead to anoxia and subsequent fish kill (Sun & Boyd, 2013). A nitrate is said to be maximum at 10 mg/L, anything above this value is considered as pollution. However, under

natural situation nitrate concentration tend to be low due to biological uptake and seasonal fluctuations (Ville, 2011).

### **2.8.9 Phosphates of inland water**

Phosphorus is a highly reactive, multivalent, non-metal of the nitrogen group in the period table, which occurs in nature in association with other elements (Bhatnagar & Devi, 2013). Phosphate rock, which contains the mineral apatite, an impure tri-calcium phosphate, is an important source of phosphorus.

Phosphorus is an essential nutrient for all living organisms; living matter contains about 0.3 percent dry weight phosphorus (Horne and Goldman 1994). It plays a major role in biological metabolism, and when compared to other macronutrients required by biota, phosphorus has the rarest abundant and commonly the first nutrient to limit biological productivity (Wetzel, 2001). Water bodies containing low phosphorus concentrations (un-impacted sites) typically support relatively diverse and abundant aquatic life that are self-sustaining and support various water uses.

However, elevated phosphorus concentrations can adversely affect aquatic ecosystems (Chambers *et al.*, 2001), which implies that; first response of an aquatic system to phosphorus additions is increased plant and algal productivity and biomass. Although this may be suitable in some cases, beyond a certain point, further phosphorus additions to phosphorus-limited systems can cause undesirable effects, such as: (i) decrease in biodiversity and changes in dominant biota; (ii) decline in ecologically sensitive species and increase in tolerant species; (iii) increase in plant and animal biomass; (iv) increase in turbidity; (v) increase in organic matter, leading to high sedimentation; and (vi) anoxic conditions (Environment Canada, 2004). When the excessive

plant growth includes certain species of cyanobacteria, toxins may be produced, causing increased risk to aquatic life, livestock, and human health (Dodds & Smith, 2016)

### **2.9.1 Morpho Edaphic Index**

The term “Morphoedaphic” was derived from the Greek; i.e. "morph": form, and "edaphos" bottom. Therefore the adjectival form "morphoedaphic" index which was defined as a function of an edaphic variable and a morphological variable (in this case morphometric), both defined with respect to the entire aquatic ecosystem. Specifically, in its simplest form it is the ratio of total dissolved solids and depth. The morphoedaphic index was first proposed by Ryder (1965) for temperate lakes (Loftus *et al.*, 1974). Later on, the model was used by Welcomme (1976) for some African lakes.

The morphoedaphic index (MEI; Ryder 1965), being a model for estimating fish yield, calculated as the concentration of total dissolved solids (TDS) divided by mean depth of the lake. This model indicates that potential fishery yield is proportional to the square root of MEI (Hansen *et al.*, 2010). Several limnological parameters such as conductivity, total dissolved solids, water quality, and phytoplankton and reservoir morphometry have been used in estimating potential fish yields from reservoirs. However conductivity is used instead of TDS (Mustapha, 2009)

Also; due to its simplicity, the morphoedaphic index had gained enormous popularity among ecologist, fish managers (Downing *et al.*, 1991). Despite its simplicity; the MEI was derived empirically (Ryder 1965), which embraced the following conceptual framework and assumptions underlying the model. These assumptions are (1) bedrock geology largely determines the concentration of TDS entering lakes; (2) TDS is a surrogate for essential nutrients, such as

phosphorus, that control lake productivity; and (3) mean depth is a surrogate for hydrological characteristics such as thermal stratification, nutrient circulation, and dilution, all of which affect how energy is processed within the water column (Hansen *et al.*, 2010).

The morphoedaphic index (MEI) has a wide applications which has being applied by many researchers to predict nutrient status and biomass in some Canadian Lakes (Chow-fraser, 1991), fish yield potentials of a sub-tropical lake, Manchar (Sindh), Pakistan was also analyzed using morphoedaphic with some other indices of productivity such as Trophic State Index (TSI) by (Jafri *et al.*, 2006), similarly the recreational fishery status of Cabra coral reservoir had been comprehensively analyzed by (Baigún *et al.*, 2006). Also (Jackson, Harvey, & Somers, 1990) successfully applied the same model with some modifications on Canadian lakes. The morphoedaphic index had been used to assess the potential yield and compare the productivity of two Sri-Lankan reservoirs (Perera, 2003). In West African lakes; the morphoedaphic has being in use to determine the productivity of inland impoundments which indeed are more productive than temperate ones (Suguna, 1995). The productivity of two Ghanaian lakes Bontanga and Libga were successfully assessed by (Quarcoopome & Amevenku, 2008), Dawhenya reservoir in Ghana after four decades of impoundment by (Alhasssan, 2011). In Nigeria; the same model has being in use for the assessment of potential yields of fish in shallow reservoirs which includes the works of Edward (2013) who evaluated the fisheries potentials of Egbe reservoir, Ekiti State, the fisheries potentials of Kubanni reservoir (ABU, Zaria) was also reported by (Balogun & Aduku, 2004), Eleiyele reservoir fisheries potentials was also reported by (Jeje, 1997).

### **2.9.2 Potential Yield**

The fishery potential of a freshwater reservoir depends on its productivity; that is, the ability of any trophic level to produce biomass. Because lower trophic levels are the food base of higher trophic levels, productivity at different levels tends to be positively correlated. Therefore, productivity of a fish assemblage is influenced by factors that limit primary production in any ecosystem (Hansen *et al.*, 2010). Obviously, there's a lot of significance towards the understanding of fish production in natural aquatic ecosystems including lakes. Fisheries management takes into account of "two really different issues: what nature can produce, and what can be done to manage the activities of those who would capture that production (Walters & Martell, 2004). Therefore, the determinants of fish productivity and potential yield should be understood and related to management of natural aquatic ecosystem. In line with the above; the model Maximum Sustained Yield (MSY) was developed to check the level of exploitation of fish stock in a natural aquatic ecosystem, the Maximum Sustained Yield is the ratio of estimated potential yield using morphoedaphic index with angler harvest (Baigún *et al.*, 2006). However, the theory of maximum sustained yield (MSY) serves as a reference point for planning a fishery, not as a goal for managing a fishery, because knowledge of MSY is critical for addressing goals related to fishing quality. For instance, if MSY is low, a lake can support quality fishing for only a few fishers. The linkage between MSY, fishing effort, and fishing quality seems obvious and is presented as a hallmark for understanding how to develop goals for fisheries (Kalff, 2002)

## CHAPTER THREE

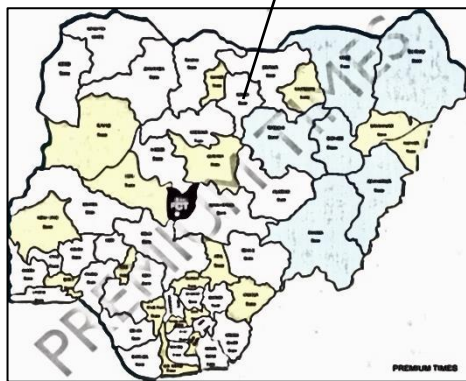
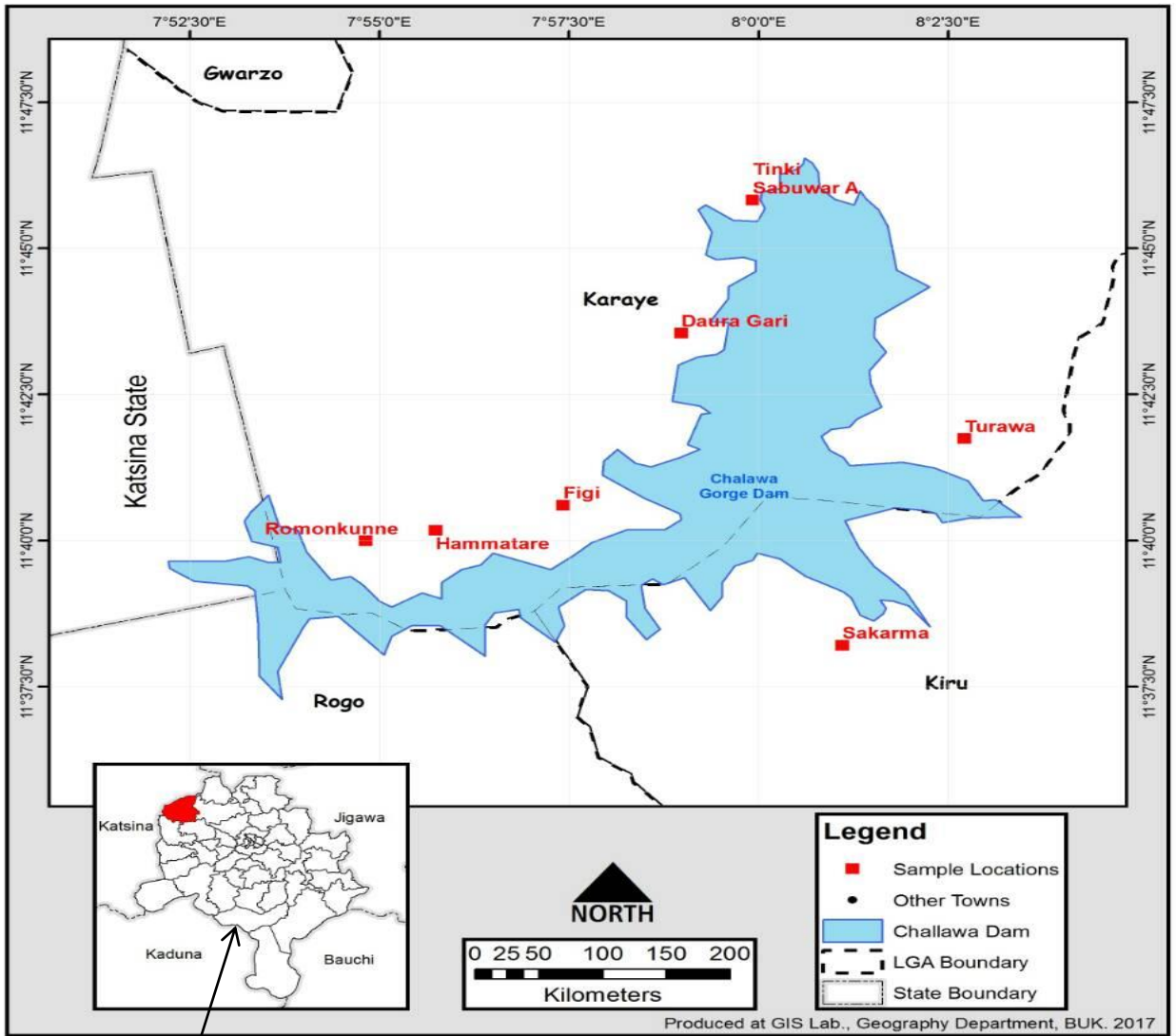
### 3.0

### MATERIALS AND METHODS

#### 3.1 Study Area

Challawa gorge dam is located at  $8^{\circ}06'58.04''$ E latitude  $11^{\circ}41'21.95''$ N longitude (Google Earth, 2016) in Karaye Local Government of Kano State in the Northwest of Nigeria, about 90 km southwest of Kano city. It is a major reservoir on the Challawa River, a tributary of the Kano River, while Kano River is the main tributary of the Hadejia River (Uyigue, 2009).

The dam was built by Julius Berger Nigeria in 1990 - 1992 using rock fill construction. It is 42 m high and 7.8 km in length. The dam has a full storage capacity of  $904,000,000 \text{ m}^3$ . The direct catchment area is  $3857 \text{ km}^2$  (World Bank, Lake Chad Basin Commission, 2002). Apart from irrigation; fishing, and township water supply, the dam was constructed with hydropower potential of around 3MW (Salihi, 2009). Due to lack of stability of the soil at the periphery of the dam, the dam is gradually being silted (U.N.E.P., 2009).



**Figure 1:** Map of Challawa Gorge Dam Showing Study Sites

### **3.2.1. Temperature**

Temperature was measured in the morning during sampling at various sampling sites using Hanna measuring instrument (combo pH/EC/TDS/T°C model HI9835). The meter was standardized with buffer solution. It was lowered into the water body and readings were taken and recorded immediately the timer stabilized.

### **3.2.2 Hydrogen ion concentration (pH)**

pH was measured in the morning at each sampling using Jenway portable pH meter (model 350). The meter was standardized with buffer solution. It was lowered into the water body and reading taken immediately the timer stabilized and hold.

### **3.2.3 Electrical conductivity**

Electrical conductivity was measured using the same Hanna measuring instrument (combo pH/EC/TDS/T°C model HI9835) and the measurement was done at the same time as above.

### **3.2.4. Total dissolved solids (TDS)**

Total dissolved solid was also measured at the same time as above and using the same Hanna measuring instrument

### **3.2.5 Salinity of the water body**

Salinity of the water body was also measured in situ for each of the sampling sites using Hanna measuring instrument (combo pH/EC/TDS/T°C model HI9835), and the mode of measurements were made as that of the latter.

### 3.2.6 Dissolved Oxygen (DO)

The dissolved oxygen level of the each of the sampling sites was measured in situ using a portable measuring device Hanna Dissolved Oxygen Meter (model HI9143).

### 3.2.7 Nitrates

5 ml of each of the sample from three distinct points (onshore, mid-shore and offshore) was taken into a test tube. Then 5 ml of 13N H<sub>2</sub>SO<sub>4</sub> was added to each of samples. 0.24 ml of Brucine reagent was added to the test samples. The mixture was then boiled in water bath (Clifton water bath) to 100°C for the period of 25 minutes and developed yellowish colour, which then was allowed to cool down in cool water. The test tubes were dried. The absorbance of this colored test samples were measured at 410nm wavelength using a Jenway spectrophotometer (model 6300). From the results of these test samples, the concentration of nitrates was measured using the expression;

$$\frac{\text{Absorbance of test}}{\text{Absorbance of standard}} \times \text{Concentration of standard (mg/L)}$$

### 3.2.7 Phosphates

5 ml of each of the sample from three distinct points (onshore, mid-shore and offshore) was taken into a test tube. Then 4.5 ml of Trichloroacetic acid was added to each of samples. 0.5 ml of standard phosphate was added to the standard. Then, 1ml of ammonium molybdate solution was added to all the test tubes. Then 1ml of metol reagent was added to each of the test tubes. The mixture was allowed to stand for the period of 30 minutes. The absorbance of this colored test samples were measured at 680nm wavelength using a Jenway spectrophotometer (model 6300). From the results of these test samples, the concentration of phosphates was measured using the expression;

$$\frac{\text{Absorbance of test}}{\text{Absorbance of standard}} \times \text{Concentration of standard (mg/L)}$$

### 3.2.8 Depth

The water depth at each station and its sub-stations (onshore, mid-shore and offshore) were measured using Ekman grab which was dropped from canoe into the water at one end, the other light end been held and the depth was measured in meter. The mean value was determined from the results of the three sub-stations.

### 3.3.1 Morpho-Edaphic Index (MEI) Determination

The Morpho-Edaphic Index (MEI) of the three selected sites were measured, using the expression as

$$\text{MEI} = \frac{\text{TOTAL DISSOLVED SOLIDS(ppm)}}{\text{MEAN DEPTH(M)}}, \text{ Which can be compared favorably with;}$$

$$\text{MEI} = \frac{\text{CONDUCTIVITY}(\frac{\mu\text{S}}{\text{cm}})}{\text{Mean depth(m)}}$$

### 3.3.2 Fish Potential Yield (Y) Estimation:

The mean value of MEI for the three selected sites were matched with the Regression Line obtained from the relationship of MEI and recorded catch from 31 African lakes (Henderson and Welcmme, 1974). Estimates of the potential fish yield were measured using the Physico-chemical characteristics of the reservoir and the relationship  $Y=23.281, \text{ MEI } 0.447$  Marshal, B.E. (1984), Where Y is the potential fish yield in Kg/ha, MEI is Morpho-Edaphic Index, which is given in  $\mu\text{S/cm}$  and is estimated by dividing the mean conductivity by the mean depth Ryder *et al.*, (1974).

The estimates of potential fish yield of the Challawa Gorge Dam (Y) was obtained from the Morpho-Edaphic Index (MEI) in kg/ ha. Also, the potential yield of the three selected sites was calculated independently and the mean was taken. Thus, the relationship

$$Y = 23.281 \times \frac{\text{Mean conductivity of 3 stations}^{(0.447)}}{\text{Mean depth}}$$

Where:

Y = Fish potential yield in Kg/ha.

### **3.3.3 Fish Relative Yield Index Determination**

As a measure of exploitation level; the relative yield index (RYI) defined by Adams and Olver (1977) was used in the assessment of exploitation level of the three selected sites. The RYI is the ratio between the observed catch and the estimated potential yield ( $RYI = Y_{obs}/Y_{est}$ ).

$RYI = (Y_{obs}/Y_{est}) \times 0.75$ . Where;

MSY = Maximum Sustainable Yield

$Y_{obs}$  = Observed yield (which can be obtained from the total weighted fish samples obtained in the field)

$Y_{est}$  = Estimated potential fish yield (obtain using MEI)

Hence, the percentage of the relative yield index (RYI) was calculated as  $RYI \times 100$ .

### 3.4.1 Determination of Fish Species Diversity

Fish species were sampled monthly from three selected sites for the period of six months (March to August, 2017). Fish samples were collected from catches of fishermen in the field, identified, sorted into species and family, enumerated and recorded. Each fish was counted and weighed individually. The fishes were caught by the fishermen using gill nets, cast nets and lift nets of various mesh sizes ranging between 5.08 cm to 17.78 cm. Fishing activities was carried out on dugout canoes.

### 3.4.2 Laboratory Analysis

In the laboratory; the fishes were sorted according to species. The number of each species caught was recorded. Each fish specimen was measured for total length as described by Olatunde, (1977) and standard weight using a balance (Sartorius T630). The fishes obtained were identified individually using the keys by Reed *et al.*, (1967), Olaosebikan and Raji (2004), [FishBase](#) identification keys 2017.

### 3.4.3 Ichthyofauna composition and Diversity

The ichthyofaunal composition of the Reservoir was estimated from the checklist of fishes obtained from identification of monthly samples. Some indices of diversity were used to describe the diversity of the fish communities in the dam as follows:

Margalef's Index (D) for species richness (Margalef, 1968).

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

Where S = number of species and N = number of individuals.

The Shannon-Wiener's Index (H') of species diversity (Shannon & Wiener, 1963);

$$H' = -\sum P_i \ln P_i \dots \dots \dots (2)$$

Where  $P_i$  is the proportion of the total number of individuals occurring in species  $i$ .

Pielou's Index (J) for species evenness (Pielou, 1969);

$$J = H' / \ln S \dots \dots \dots (3)$$

Where  $H'$  is the species diversity index and  $S$  is the number of species.

**3.4.4 Determination of Condition factor (K):**

Representative fish samples from the three selected sites were selected monthly and were weighed to the nearest 0.1g using weighing balance (Sartorius). The standard lengths were measured to the nearest 0.1cm on a measuring board. Fulton's condition factor was calculated for each of the species, using the expression  $k = 100W/(L^B)$  as cited in (Nazeef & Abubakar, 2013).

Where

$$B = 3$$

$W$  = weight (g)

$L$  = length in (cm).

**3.4.5 Data Analysis**

Incurred data obtained from MEI, Yield determination, and condition factor of fish species from the three selected sites were analyzed using ANOVA on Minitab Statistical tool (V 18). Two-way analysis of variance at 0.05 probability levels was used to test for the effects of variations due to sampling error, sampling stations (sites), the Physico-chemical factors, fish abundance, fish abundance within family, fish condition factor(K) and weight by family and species level.

Analysis of co-variance was used to investigate the correlation and level of dependence among the Physico-chemical factors; fish abundance on selected Physico-chemical factors, fish weight on selected Physico-chemical factors, and fish abundance. In these analyses of co-variance, the test variables were sampling sites, fish species. Statistical differences were considered at  $P \leq 0.05$ .

## CHAPTER FOUR

### 4.0

### RESULTS

#### 4.1 Physico-chemical parameters

##### 4.1.1 Temperature

The monthly mean temperature variation of the three stations is presented in Table one. The temperature ranged from  $25.90 \pm 1.19$  °C to  $26.28 \pm 0.94$  °C. The lowest temperature recorded is 23.5°C which was obtained during the dry season (March) at site 3 (Turawa). However, the highest temperature value recorded is 27.5°C which was recorded at site 2 (Sakarma) during the rainy season (August).

Analysis of variance at 0.05 probability level ( $P < 0.05$ ) shows a significant difference in the seasonal temperature of the reservoir (Table 1). Wet season temperature was higher than the dry season. No significant difference was seen among the stations (Table 1).

##### 4.1.2 Dissolved oxygen

The mean monthly variation of dissolved oxygen is presented in Table 1. The dissolved oxygen ranges from the lowest value of  $6.66 \pm 0.64$  to the highest value of  $7.19 \pm 0.60$  mg/L. The lowest dissolved oxygen value recorded was 6.31 mg/L in April at site 2 (Sakarma). However, the highest value recorded was 7.98 mg/L in March at site 2 (Sakarma).

Analysis of variance at 0.05 probability level ( $P < 0.05$ ) shows no significant difference in the seasonal distribution of dissolved oxygen of the reservoir. No significance difference was seen amongst the stations as well as the seasons (Table 1).

##### 4.1.3 Conductivity

The mean monthly variation of conductivity was presented in Table 1. The values recorded ranged from  $81.52 \pm 8.41$  μS/cm to  $87.50 \pm 5.04$  μS/cm. The lowest value recorded is 68.20

$\mu\text{S}/\text{cm}$  in March at site 3 (Turawa), however the highest value was  $93.60 \mu\text{S}/\text{cm}$  in the month of June at site 2 (Sakarima).

Analysis of variance at 0.05 probability level ( $P < 0.05$ ) shows no significant difference in the seasonal conductivity of the reservoir. No significance difference was seen amongst the stations as well as the seasons (Table 1).

#### **4.1.4 Nitrates**

Mean monthly variation of nitrates was presented in Table 1. Values ranged from as low as  $8.25 \pm 3.34 \text{ mg}/\text{L}$  to as much as  $10.13 \pm 3.96 \text{ mg}/\text{L}$ . The least value recorded was  $3.80 \text{ mg}/\text{L}$  in March at site 3 (Turawa), and the highest value recorded was  $13.90 \text{ mg}/\text{L}$  in sites 1 and 2 (Feginma and Sakarima).

Analysis of variance at 0.05 probability level ( $P < 0.05$ ) revealed a significant difference in the abundance of nitrates seasonally; with the wet season being more abundant than the dry season. However, there was no significance difference among the study sites.

#### **4.1.5 Phosphates**

In the course of this study; no phosphate was found with the applied methods and tools used (Table 1). This might be due to the salt's rarity in the earth's crust.

#### **4.1.6 Salinity**

Salinity of the study sites is presented in Table 1. The salinity ranged from 0.1 % to 0.2 %. However, site 1 and 3 (Feginma and Turawa) had 0.2 %, whereas site 2 (Sakarima) had 0.1 % salinities respectfully.

#### 4.1.7 Water pH

The pH of the three sites of Challawa dam is presented in Table 1. Site 3 (Turawa) recorded the lowest pH value of 7.23 consecutively for two months (March and April), However, the highest pH value was also recorded in the same site with 7.72.

Analysis of variance at 0.05 probability level showed that there is no significant between the sites studied (Table 1)

**Table 1:** Physico Chemical parameters of the three selected sites

Characteristics	Study sites			P value
	Feginma	Sakarma	Turawa	
Geographical Coordinates	N 11° 39' 28.1" E 007° 581' 18.9"	N 11° 39' 54.3" E 008° 00' 611"	N 11° 40' 52.4" E 008° 02' 31.9"	ND
Elevation (M)	518	527	518	ND
Mean Depth (M)	4.49 ± 0.43 <sup>a</sup>	3.36 ± 0.61 <sup>b</sup>	2.53 ± 0.61 <sup>b</sup>	0.00 0.10*
Temperature (°C)	26.28 ± 0.94 <sup>a</sup>	25.90 ± 1.19 <sup>a</sup>	26.15 ± 1.51 <sup>a</sup>	0.86 0.04*
Dissolved oxygen (mg/L)	6.72 ± 0.57 <sup>a</sup>	6.66 ± 0.64 <sup>a</sup>	7.19 ± 0.60 <sup>a</sup>	0.29 0.06*
Conductivity (µS/cm)	87.50 ± 5.04 <sup>a</sup>	83.57 ± 6.00 <sup>a</sup>	81.52 ± 8.41 <sup>a</sup>	0.31 0.05*
Phosphates (mg/L)	0.0	0.0	0.0	ND
Nitrates (mg/L)	10.13 ± 3.96 <sup>a</sup>	10.09 ± 2.32 <sup>a</sup>	8.25 ± 3.34 <sup>a</sup>	0.53 0.00*
Salinity (%)	0.2	0.1	0.2	ND
pH	7.33 ± 0.12 <sup>a</sup>	7.36 ± 0.13 <sup>a</sup>	7.37 ± 0.20 <sup>a</sup>	0.90

Columns with different superscripts letter are significantly different. (\*) indicates seasonal P value of variables. ND implies no data.

#### 4.2.0 Fish species identified

A total of ten (10) species were recorded over a period of six months March to August, 2017 (Table 2). These species belong to nine families, family Mormyridae has the highest number of species represented by *Marcusenius isidori* and *Marcusenius senegalensis*. Besides family Mormyridae, the other families were represented by one species each. Family Bagridae was represented by *Bagrus bayad macropterus*. Family Latidae represented by *Lates niloticus*, family Alestidae was represented by *Brycinus nurse*, *Oreochromis niloticus* represented family Cichlidae, family Claridae was represented by *Clarias lazera*, *Auchenoglanis occidentalis* represented the family Claroteidae, whereas *Synodontis schall* represented family Mochokidae. And *Schilbe mystus* represented the family Schilbeidae (Table 2).

**Table 2:** Fish species identified in Challawa Dam

Family	Species	English name	Local name (Hausa)
<b>Bagridae</b>	<i>Bagrus bayad macropterus</i>	Silver catfish	Ragon ruwa
<b>Latidae</b>	<i>Lates niloticus</i>	Nile perch	Giwan ruwa
<b>Alestidae</b>	<i>Brycinus nurse</i>	Silversides fish	Kawara
<b>Cichlidae</b>	<i>Oreochromis niloticus</i>	Nile tilapia	Karfasa
<b>Claridae</b>	<i>Clarias lazera</i>	Catfish	Tarwada
<b>Claroteidae</b>	<i>Auchenoglanis occidentalis</i>	Bubu, armored Catfish	Buro
<b>Mochokidae</b>	<i>Synodontis schall</i>	Wahrindi	Karaya
<b>Mormyridae</b>	<i>1.Marcusenius isidori</i>	Trunkfish	Farinwata
	<i>2.Marcusenius senegalensis</i>		Data
<b>Schilbeidae</b>	<i>Schilbe mystus</i>	Butterfish	Balo

#### 4.2.1 Fish species composition

The monthly distribution of fish stock is presented on Table 3. The table shows the total of ten (10) species belonging to nine (9) families. Family Mormyridae has the highest number of species represented by *Marcusenius isidori* and *Marcusenius senegalensis*, whereas the remaining families had one species each (Table 2).

A total of 4285 fish samples were caught during the study period. However, apart from family Mormyridae; all the other families had 100% species representation.

A total of 123 of *Auchenoglanis occidentalis* were caught during the study which account for 2.87% of the total fish caught. The species had a 100% species representation of the family Claroteidae. The family Claroteidae is the second to the lowest family in terms of number of individuals. Family Latidae had only *Lates niloticus* with a total of 106 fish samples caught which accounted for 2.47% of the total fish stock.

*Marcusenius senegalensis* had the highest number of individuals with 1397 fish samples caught and accounted for 60.73% within family abundance and 32.60% of the total fish stock caught. This is followed by *Marcusenius isidori* with a total of 902 individuals accounting for 39.27% within family abundance and 21.05% of the total fish stock. All these species belong to the same family Mormyridae. This is followed by *Oreochromis niloticus* with 534 total fish samples accounting for 12.46% of the total fish caught.

The remaining families' representative had less than 9% of the total fish stock each which includes *Brycinus nurse* 8.35%, *Schilbe mystus* 5.88%, *Bagrus bayad macropterus* 5.67% and *Clarias lazera* 5.15% respectfully (Table 3).

**Table 3:** Monthly distribution of fish stock

<b>Species/ Month</b>	<b>MONTH</b>						<b>Total</b>	<b>%</b>
	<b>March</b>	<b>April</b>	<b>May</b>	<b>June</b>	<b>July</b>	<b>August</b>		<b>Abundance</b>
<i>Auchenoglanis occidentalis</i>	0	0	31	56	20	16	123	2.87
<i>Bagrus bayad</i>								
<i>Macropterus</i>	3	31	49	46	55	59	243	5.67
<i>Brycinus nurse</i>	1	63	187	35	42	30	358	8.35
<i>Clarias lazera</i>	14	41	63	49	35	19	221	5.15
<i>Lates niloticus</i>	1	30	15	29	27	04	106	2.47
<i>Marcusenius isidori</i>	6	177	204	319	186	10	902	21.05
<i>Marcusenius senegalensis</i>	6	297	402	390	294	08	1397	32.60
<i>Oreochromis niloticus</i>	9	104	228	109	58	26	534	12.46
<i>Schilbe mystus</i>	2	28	69	49	67	37	252	5.88
<i>Synodontis schall</i>	2	30	54	38	11	14	149	3.47
<b>Grand Total</b>								4285

#### 4.2.2 Diversity indices

Margalef's diversity index	1.07
Shannon Wiener's species richness	2.28
Pielou's index for species evenness	0.99

#### 4.2.3 Fish Weight and Condition Factor

The weight composition and condition factor of fish species is presented in Table 4. The table revealed that out of the ten (10) species; *Bagrus bayad macropterus* of the family Bagridae has the highest weight composition with 22748.2g by weight and accounted for 39.84% of the total biomass caught, this is followed by *Lates niloticus* of the family Latidae with a total biomass of 10657.4g and accounted for 18.66% of the total fish biomass caught.

*Marcusenius senegalensis* and *Marcusenius isidori* both of the family Mormyridae had the lowest biomass composition 419.5g and 241.3g accounting for 0.73% and 0.42% of the total biomass. The rest of the species have their biomass ranged from 0.91% to 11.59% respectfully.

Analysis of variance at 0.05 probability level ( $P < 0.05$ ) revealed a significant difference in the biomass composition between species and between the study sites.

The fish condition factor of each of the species identified is presented in Table 4. The table revealed that *Marcusenius senegalensis* has the highest K- value with 2.0. This is followed by *Oreochromis niloticus* with a K- value of 1.95. *Brycinus nurse* is next with a K-value of 1.31. A significant number of species had their K-value within the range of 1.03 to 1.22; which of course includes *Marcusenius isidori* and *Lates niloticus*. The remaining species represent the lowest K-value within the range of 0.71 to 0.88 (Table 4).

Analysis of variance at 0.05 probability level ( $P < 0.05$ ) revealed a significant difference in the K-value between the species, but there's no significant difference between the sites in terms of K-value.

**Table 4:** Fish species weight and condition factor

<b>Fish Species</b>	<b>Total weight (g)</b>	<b>% Total weight (g)</b>	<b>Condition factor (K)</b>
<i>Auchenoglanis occidentalis</i>	4351.1 <sup>b</sup>	7.62	0.87 <sup>b</sup>
<i>Bagrus bayad</i>	22748.2 <sup>a</sup>	39.84	0.87 <sup>b</sup>
<i>Brycinus nurse</i>	520.2 <sup>c</sup>	0.91	1.31 <sup>b</sup>
<i>Clarias lazera</i>	5907.5 <sup>b</sup>	10.34	0.88 <sup>b</sup>
<i>Lates niloticus</i>	10657.4 <sup>b</sup>	18.66	1.03 <sup>b</sup>
<i>Marcusenius isidori</i>	419.5 <sup>c</sup>	0.73	1.22 <sup>b</sup>
<i>Marcusenius senegalensis</i>	241.3 <sup>c</sup>	0.42	2.00 <sup>a</sup>
<i>Oreochromis niloticus</i>	6621.5 <sup>b</sup>	11.59	1.95 <sup>a</sup>
<i>Schilbe mystus</i>	2324.8 <sup>c</sup>	4.07	0.71 <sup>b</sup>
<i>Synodontis schall</i>	3304.4 <sup>b</sup>	5.78	0.87 <sup>b</sup>

Column(s) with different superscript letter are significantly different.

#### **4.3.1 Morpho Edaphic Index (MEI)**

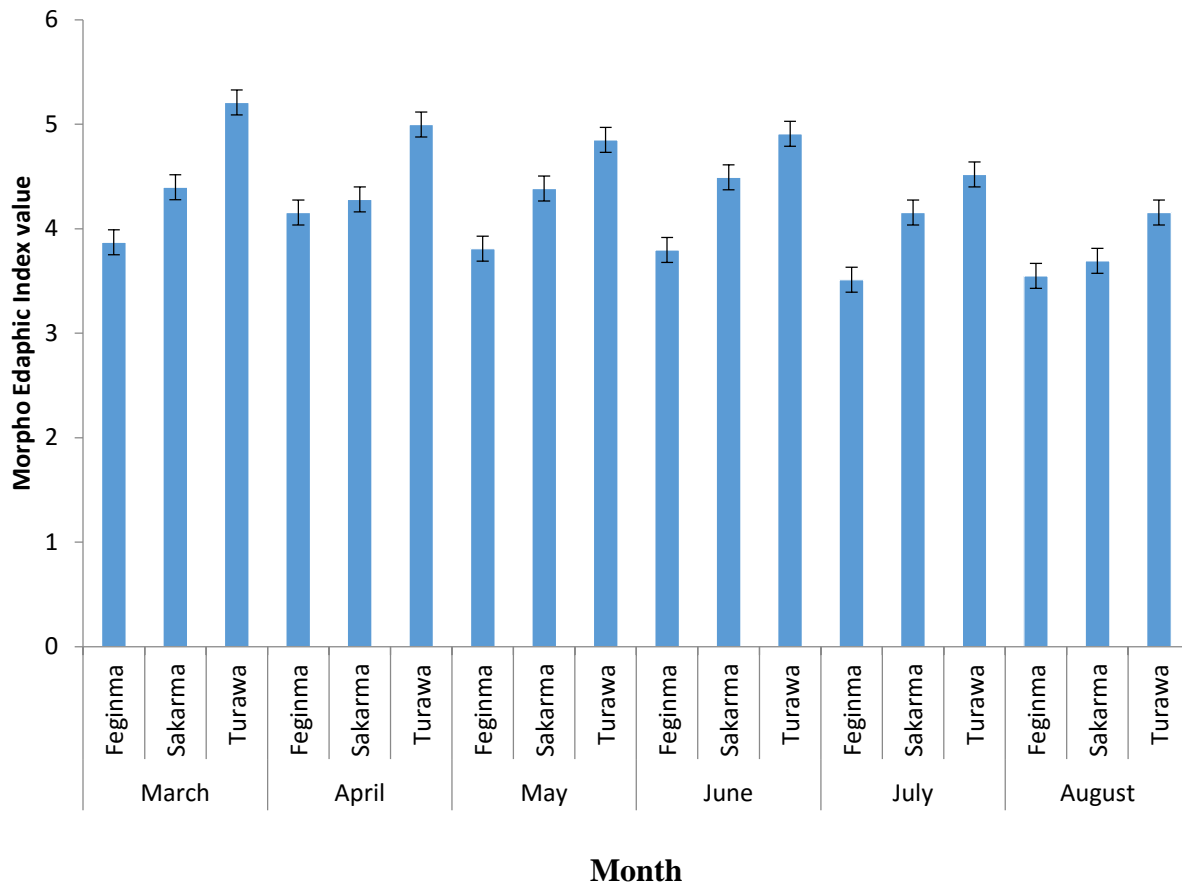
The morpho-edaphic index of the three landing sites is presented in Figure 2. The figure shows that the highest value recorded was 5.20 recorded at site 3 (Turawa), and the lowest value of 3.51 was recorded in site 1 (Feginma).

Analysis of variance at 0.05 probability level ( $P < 0.05$ ) showed that there is significant difference among the sites and as well as the two seasons considered, with each of the sites varying from each other (Table 5).

**Table 5:** Morpho Edaphic Index and Potential Yield of the study sites

<b>Characteristics</b>	<b>Study sites</b>			<b>P value</b>
	<b>Feginma</b>	<b>Sakarma</b>	<b>Turawa</b>	
General Morpho Edaphic Index (MEI)	3.78 <sup>b</sup>	4.23 <sup>b</sup>	4.77 <sup>a</sup>	0.00
Seasonal MEI (Dry season)	3.94 <sup>c</sup>	4.35 <sup>b</sup>	5.01 <sup>a</sup>	0.00
Seasonal MEI (Wet season)	3.61 <sup>b</sup>	4.11 <sup>ab</sup>	4.52 <sup>a</sup>	0.04
General Potential Yield (Kg/ha)	88.05 <sup>b</sup>	98.56 <sup>b</sup>	111.12 <sup>a</sup>	0.00
Seasonal Potential Yield (Dry season) (Kg/ha)	91.84 <sup>c</sup>	101.38 <sup>b</sup>	116.83 <sup>a</sup>	0.00
Seasonal Potential Yield (Wet season) (Kg/ha)	84.26 <sup>b</sup>	95.75 <sup>ab</sup>	105.40 <sup>a</sup>	0.04

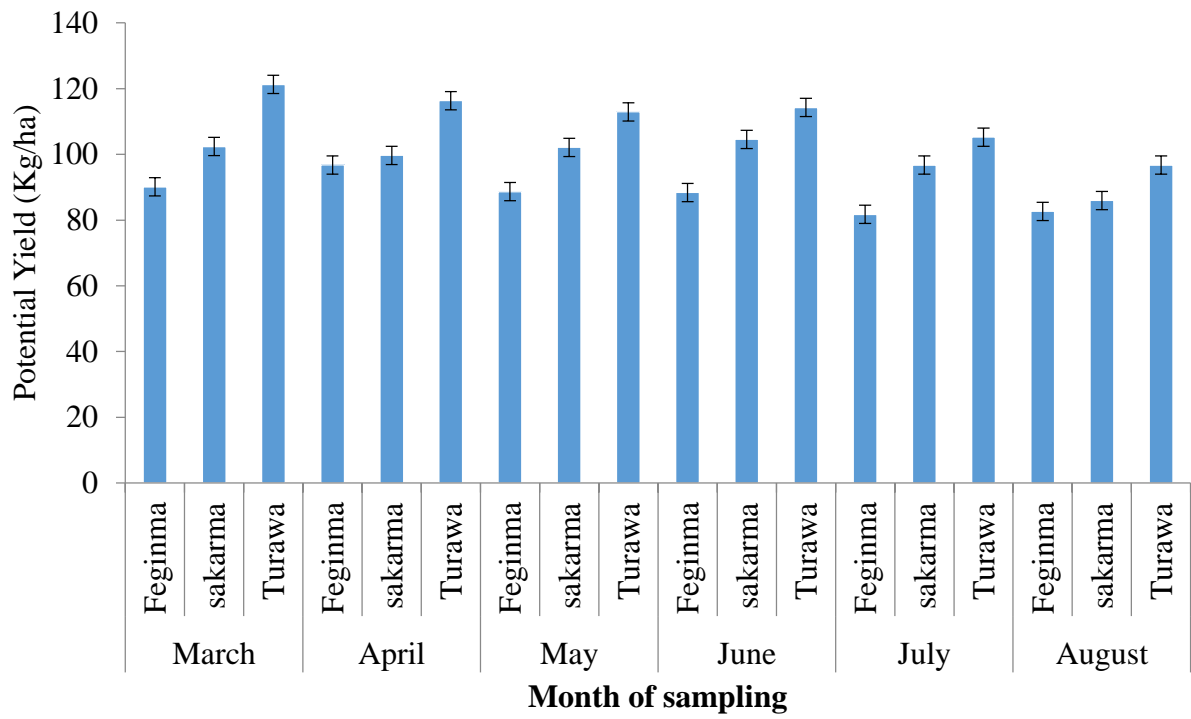
Column(s) with different superscript letter are significantly different.



**Figure 2: MEI value distribution among the study sites**

### **4.3.2 Fish Potential Yield**

The potential yield of the three study sites of the Challawa dam were analyzed and presented in figure 1. The results revealed that the potential yield of fish ranged from the lowest value of 81.74 Kg/ha recorded at site 1 (Feginma) in the month of June and the highest value recorded is 121.25 Kg/ha at site 3 (Turawa) in the month of March (Figure 3).



**Figure 3: Monthly Potential Yield of Fish Species of Challawa Dam**

## DISCUSSION

### 4.4 Discussion

Associated with any ecological changes of a natural reservoir are rainfall, wind and solar energy which serve as driving forces (Mustapha, 2009), besides these; nutrient inputs, hydrology and other chemical parameters account for the population dynamics of a natural aquatic ecosystem (Chalar & Tundisi, 1999).

#### 4.4.1 Fish species composition

In this study, a total of ten (10) species belonging to nine (9) families were identified and recorded with mormyrids being the dominant species in the fish community. This fish species composition of Challawa gorge dam is in line with the works of (Oyewo, 2015) where twelve (12) species belonging to six (6) families were recorded at Dogon ruwa water body with cichlids being dominant species, and (Dankishiya *et al.*, 2013) reported eleven (11) species belonging to five (5) families from Usuma Reservoir. However, the fish species composition of Challawa dam is higher than that of Ahmad *et al.*, (2014), who reported a total of eight (8) species belonging to four (4) families in Katsina State water body. This may be due to the large size of Challawa dam which may accommodate large volume of species. However, the Challawa dam fish species composition is lesser than the findings of (Ja'afaru and Abubakar, 2015) who reported twenty six (26) species belonging to 14 families with bagrids and mormyrids being the dominant species in Dadin-kowa dam, fifteen (15) species belonging to eleven (11) families were reported in the same Dadin-kowa dam (Nazeef & Abubakar, 2013). The low species representation of the Challawa dam as compared to the aforementioned study sites may be due to the large size of dam, riverine tributaries, moderate fish exploitation and different lake-basin morphometry.

In this study; the dominance of mormyrids followed by cichlids is in line with the findings of Abubakar (2015) and (Arome & Ugondo, 2014). The abundance in terms of species and number, this large number of individuals may be due to the availability of phytoplankton, diverse food supplements, prolific capabilities and good parental care as stated by Ayamre and Ekelemu, (2016). Also Mustapha (2009) stated that fish adaptability to lacustrine environment attributes to their dominance.

However, *Lates niloticus* with one hundred and six individuals (106) had the least abundance. This may be due to their food preference, being carnivorous; their low abundance will serve as a checkmate for the most prolific species such *Marcusenius senegalensis* and of course it's desirable nature by humans.

The number of fish species present in natural aquatic ecosystem (species richness) increases with lake size, presumably because lake size is correlated to habitat diversity (Kalff, 2002). Species richness in natural lakes is also affected by physical (latitude and altitude) and chemical parameters (such as TDS, pH, conductivity) attributes of individual lakes (Hansen *et al.*, 2010).

#### **4.4.2 Fish species biomass composition**

The fish species biomass recorded 57.09 Kg, out of which *Bagrus bayad macropterus* had the highest percentage biomass which constitute 39.04% of the total species biomass composition this was followed by *Lates niloticus* with 18.66%. These findings coincided with the findings of Ja'afaru and Abubakar (2015) where bagrids were the dominant species. Attributable to the biomass dominance of *Bagrus bayad macropterus* and *Lates niloticus* may be due to their carnivorous nature, low population in this study which allow lesser competitions for food, shelter which are of course are core requirements for good growth and weight gain, the *Lates niloticus*

have defensive mechanism which allow the species to avoid predation at juvenile stage. Also, the lower trophic level is made up of abundant mormyrids (*Marcusenius isidori* and *Marcusenius senegalensis*) which served as good source of food to the latter species.

On the contrary to the above; mormyrids in this study formed the least fraction of the fish species biomass composition which accounted to 0.73% and 0.42%. This low biomass may be due to their relative small size, high proliferation, intensive intra-species competition, predation and seasonal changes of lacustrine environment.

#### **4.4.3 Fish species condition factor (K)**

Condition factor (K) as applied to fish biology is an index that reflects the interplay between biotic and abiotic factors in the physiological condition of fish (Lizama & Ambrosio, 2002). In this study, the condition factor showed that out of the ten (10) species identified; 50% of these species had K values within the range of 0.01 to 0.87 with *Schilbe mystus* having the least K value of 0.71, this K value coincides with K values of *Polypterus ansorgei* as recorded by Enetimi (2016). The other 50% had K values within the range of 1.0 to 2.0 with *Marcusenius senegalensis* having the highest K value of 2.0, this result is in line with the K values of *Tilapia zilli* (Nehemia, 2012). K values, is not constant for individuals, species, population but is subject to wide variations for fish of an average natural conditions (Nazeef & Abubakar, 2013), the results of this study showed below and average of fish. Generally however the differences in K values between and within species are attributable to the differences in stress level, sex, season, availability of feeds, and water quality parameters (Nehemia *et al.*, 2012). In this study, the 50% of species with low or below K values may had been subjected to uncontrolled exploitation through the use of non-selective gears (Yan taru).

#### **4.4.4 Potential Fish Yield**

The reservoir's fish estimates obtained is 99.84 kg/ha, this yield agrees with the statement of Mustapha (2009) who stated that shallow tropical reservoirs are more productive than deeper temperate lakes, hence the fish yield from Challawa dam obtained is similar to the ones found from the works of other researchers such as Oyun (125.72 kg/ha) Mustapha, (2009) in Nigeria, Botanga (86.98 kg/ha) and Libga (97.19 kg/ha) Quarcoopome *et al.*, (2008) in Ghana.

The yield of the Challawa dam is however higher than the yield of the other tropical reservoirs such as Kubani (38 kg/ha) Balogun and Aduku, (2005); Kainji (3.5 – 4.7 kg/ha) Balogun and Ibeun, (1995). However, the high potential yield may be as a result of high conductivity with low depth, hence according to Jackson, (2001), shallow reservoirs in the tropics are said to be more productive than those in the temperate regions.

#### **4.4.5 Relative Yield Index**

The relative yield intensity (RYI) recorded 0.43 which account for 43%, this result coincides with the finding of Jenkins (1982) as cited by Baigún *et al.*,(2006), however lower than the one reported by Mosa and Regidor (2003) with 80% as cited by Baigun *et al.*,(2006). Attributable to the differences in RYI are the differences in salinity of water, conductivity, species biomass and biomass accumulation, food conversion efficiencies, biomass composition of estimated species, and potential fish yield estimates. The Relative Yield Index of the Challawa dam cannot be expressed as being overexploited ( $RYI < 1$ ). And indicated that the dam is rich. According to Adams and Olver (1977) as cited by (Baigún *et al.*, 2006) RYI value less than 1 indicates moderate exploitation of fish stock.

#### **4.4.6 Physico Chemical Parameters**

The study of the Physico-chemical properties of water which is a fundamental part of limnology with diverse usage to the assessment of water quality, biological productivity and trophic status, as well as composition, distribution and abundance of biotic organisms (Mustapha, 2009).

#### **4.4.7 Dissolved oxygen**

Dissolved oxygen is virtually an integral component to life in aquatic environment as it affects the physiology and distribution of the aquatic organisms EPA (2013). Dissolved oxygen is virtually an integral component to life in aquatic environment as it affects the physiology and distribution of the aquatic organisms. In freshwaters, dissolved oxygen at sea level ranges from values of  $15\text{mg l}^{-1}$  at  $0^{\circ}\text{C}$  to  $8\text{mg l}^{-1}$  at  $25^{\circ}\text{C}$ . Concentrations in unpolluted waters are usually close to, but less than  $10\text{mg l}^{-1}$  (Alhassan, 2011). Concentrations below  $2\text{mg l}^{-1}$  may lead to the death of most fish. The dissolved oxygen range of 6.35 to  $7.64\text{mg l}^{-1}$  indicates a good range of dissolved oxygen that can support fish and aquatic life in Challawa dam.

#### **4.4.8 Conductivity**

As defined by EPA (2012), conductivity refers to the measure of water's capability to pass electrical flow and is usually measured in micro or millisiemens per centimeter. This ability is directly related to the concentration of ions in the water. The highest conductivity value of  $93.60\mu\text{Scm}^{-1}$  recorded in June from site 2 (Sakarma), this value recorded may be due to the influx of suspended particles as well as agricultural inputs from the nearby settlement; this will increase the salinity content of the water body. Site 3 (Turawa) recorded the lowest conductivity value with  $68.20\mu\text{Scm}^{-1}$  in March; this may be due to the continuous uptake of ionic compounds

by phytoplankton in the dry season. However, water with extreme conductivity value decrease species number in aquatic ecosystem according to Dumont (1999) as cited by Mustapha (2002).

Conductivity has been used to estimate potential yield of fish in an inland aquatic ecosystem as it was applied by researchers such as Alhassan, (2011), Edward (2013) and Mustapha (2009). Challawa dam conductivity range falls within range of acceptable limit for aquatic ecosystem.

#### **4.4.9 Water pH**

No chemical concept, dependent upon a mathematical twist has been received more enthusiastically by ecologists than pH (Talling, 2010). The pH ranges fall within 7.23 to 7.72 throughout in this study. The recommended pH range for most fish is between 6.0 and 9.0 with a minimum alkalinity of 20 mg/L, with an ideal CaCO<sub>3</sub> levels between 75 and 200 mg/L (Wurts *et al.*, 1992), therefore, these values are favorable for the good growth and survival of fish species.

#### **4.5.1 Temperature**

Dependent upon geomorphic conditions and local climate; temperature is a fundamental factor that influences the distribution of aquatic organisms. Water temperature comes from solar radiation by direct absorption (Berman & Steinman, 1998). In this study, temperature values fall within the range of  $25.90 \pm 1.19$  °C to  $26.28 \pm 0.94$  °C and analysis of variance at 0.05 showed that there was significant difference in the seasons with the wet season having higher temperature values. These findings are in line with the findings of Oyewo (2015). Martinez-Placious *et al.*, (1993) suggested that the temperature range of 20°C to 30°C for fish is good; this therefore shows that the temperature values of this studies is good for the survival of fish.

#### **4.5.2 Nitrates**

The availability of nitrate in an aquatic ecosystem reflects the characteristic of the surrounding environment and including bedrock. The nitrate range falls within  $8.25 \pm 3.34$  mg/L to as much

as  $10.13 \pm 3.96$  mg/L. Sites 1 and 2 (Feginma and Sakarma) recorded the highest value with 13.96 mg/L, these two sites are well surrounded by active farmlands, therefore there is an influx of chemical fertilizers (especially NPK) in the water body. This maybe the possible cause of high nitrates contents. Nitrate is an essential nutrient for land and aquatic plants however excess nitrate can lead to anoxia through eutrophication and subsequent fish kill (Sun & Boyd, 2013) and cause loss of aquatic biodiversity. Effective measures should be applied to stabilize nitrate influx and its associated threats.

### **4.5.3 Water Salinity**

Dissolved salts are basically electrolytes, these electrolytes form ionic particles as they dissolve with each a positive and negative charge, as such salinity is an attribute to conductivity and can be measured in percentages (Sommer, 2004). Salinity value in this study fluctuates within 0.1% to 0.2% throughout. This range is low and therefore favorable for aquatic lives.

## **CHAPTER FIVE**

### **5.0 CONCLUSION AND RECOMMENDATION**

#### **5.1 Summary**

The fish species compositions of the three sites of Challawa dam were studied over the six months period (March to August, 2017). Ten (10) species were identified belonging to nine (9) families with mormyrids being the dominant species. The condition of fish species identified showed a 50-50 ratio of below and average condition as classified by Lagler (1958).

The potential fish yields of the three sites of Challawa dam were assessed using Morpho Edaphic Index (MEI), all the studied sites showed a good estimate above many other tropical lakes. Fish stock exploitation levels of the three sites were analyzed using Relative Yield Index (RYI), which revealed all the sites were moderately exploited with RYI less than 1 (RYI<1).

Physico-chemical parameters analyzed revealed with the exception nitrate, are in good standing to support fish production.

#### **5.2 Conclusion**

The Challawa gorge dam surface water status can be said to be a good one reflecting on the assessment of its Physico chemical parameters which includes dissolved oxygen, nitrate, pH and electrical conductivity. These parameters were found to be within the acceptable range for the fish production and irrigation. There is a tendency of eutrophication of the Challawa dam; as the nitrate level recorded in sites 1 and 2 (Feginma and Sakarma) are relative higher as a result of influx of nitrates solution from surrounding farmlands.

The estimated potential yield of these study sites showed that all the sites are considerably productive and surpasses the results of other lakes such as Kubani reservoir (38 kg/ha) Balogun and Aduku, (2005); Kainja (3.5 – 4.7 kg/ha) Balogun, (1995). These yield estimates can be

maintained for good economic growth, suitable habitat for fish. Also, the exploitation assessed revealed that the three sites are moderately exploited ( $RYI < 1$ ).

Assessment of fish species biodiversity shows that 10 species were identified belonging to 9 families with the mormyrids (*Marcusenius isidori* and *Marcusenius senegalensis*) being the dominant species. *Lates niloticus* has the least distribution, hence it is carnivorous. The least number of *Lates niloticus* can serve as a checkmate on the proliferous mormyrids species.

Condition factor (K value) of fish species identified revealed that 50% of the species studied had their K value below 1, whereas the remaining 50% had above, these values represent below and average wellbeing of fish.

The maintenance of good Physico-chemical parameters and their influx into water system, sufficient regulation of fishing and its practices, non-selective gears restriction and enforcement by relevant authorities, public enlightenment on the dangers of biodiversity loss can greatly enhance and maintain the dynamics of the dam.

### **5.3 Recommendations**

1. Influx of nitrates from the surrounding vegetation should be checked regularly, and develop means of tackling its associated threat.
2. Relevant authority should fully enforce laws with regards to gears used for fishing and punish any individual found guilty.

## REFERENCES

- Adeniji, H.A., (1991). *Limnology and biological production in the pelagic zone of Jebba Lake, Nigeria*. PhD Thesis. University of Ibadan, Nigeria.
- Ahmad, M., Shagari, F. U., & Sani, A. N. (2014). Fish biodiversity and fishing methods of some waterbodies in Katsina State of Nigeria, *1*(6), 218–221.
- Ahmed, E. O., Ali, M. E. and Aziz, A. A. (2011). Length-weight Relationships and Condition factors of six fish species in Atbara River and Khashm el- girba Reservoir, Sudan. *International Journal of Agricultural Sciences*, **3**(1): 65-70.
- Alhassan, E. H. (2011). Limnological Evaluation of the Fisheries Potentials of a Ghanaian Reservoir, *7*(2), 91–97.
- Ali, Ja'afaru and Abubakar, U. . (2015). Fish Species Diversity and Abundance of Dadin Kowa Dam , Gombe State Nigeria Abstract :, *4*(6), 374–378.
- Andem, A., Joseph, I., George, E., & Ubong, G. (2013). Length-weight relationship and Fulton ' s condition factor of brackish river prawn ( *Macrobrachium macrobrachion* , Herklots , 1851 ) from great Kwa river , Obufa Esuk beach , Cross river state , Nigeria, *3*(3), 722–730.
- APHA (American public Health Association) (1998). Standard methods for the examination of water and waste water. 20th, edition. American public Health Association Inc, New York. 1193pp.
- Arome, G., & Ugondo, M. (2014). Fish Species Diversity and Abundance of Gubi Dam , Bauchi State of Nigeria, *3*(1), 60–67.
- Ayamre, E.U, And Ekelemu, J. . (2016). Abundance and Distribution of Fish Species in Three Water Bodies in Asaba Metropolis , Delta State , Nigeria ., *5*(1), 149–154. <http://doi.org/10.15640/jaes.v5n1a15>
- Babatunde, D.O and Raji, A. (2004): Field guide to Nigeria freshwater fishes. Federal College of Freshwater Fisheries Technology. New Bussa Nigeria. 104pp.
- Baigún, C. B., Ernal, R. B., Arrientos, D. B., Uñoz, L. M., Arros, E. B., & Auad, J. S. (2006). The recreational fishery in cabra corral reservoir ( Argentina ): A first comprehensive analysis, *30*(1), 125–130.
- Balogun, K., & Aduku, U. J. (2004). Predicting fisheries potentials, of inland reservoirs and lakes , case study of Kubanni Dam., 844–850.
- Berman, T. and Steinman, B. (1998): Phytoplankton development and turbulent mixing in Lake Kinneret (1992-1996). *Journal of plankton research* **20**: 709-726.
- Biswass, S. (1978): Observations on phytoplankton and primary productivity in Volta Lake, Ghana. *Verh.Internat. Verein. Limnol.* **20**: 1672-1676.
- Bhatnagar, A., & Devi, P. (2013). Water quality guidelines for the management of pond fish culture, *3*(6), 1980–2009. <http://doi.org/10.6088/ijes.2013030600019>

- Bialkowski, S. (2006). Carbon Dioxide and Carbonic Acid. In Chemistry 3650; Environmental Chemistry . Retrieved from <http://ion.chem.usu.edu/~sbialkow/Classes/3650/Carbonate/Carbonic%20Acid.html>
- Bottrell, H.H., Duncan, A., Gliwicz, Z.M., Grygiererek, E., Herzig, A., Hillbricht- Ilkowska, A., Kurasawa, H., Larson, P. and Weglenska, T. (1976): A review of some problems in zooplankton studies. *Norwegian Journal of Zoology* 24: 419-456.
- Casanoves, F., Alejandro, J., & Rienzo, D. (2012). Functional Diversity Indices, (January). <http://doi.org/10.1007/978-94-007-2648-2>
- Challawa Gorge Reservoir" (PDF). United Nations Environment Program. Archived from the original (PDF) on 2009-05-09. Retrieved 2009-10-03.
- Chalar, G. and Tundisi, J.G. (1999): Main processes in the water column determined by wind and rainfall at Lobo (Broa) Reservoir. Implications for phosphorous cycling. In: Tundisi, J.G and Straskraba, M. (eds.) 1999. *Theoretical Reservoir Ecology and its Applications*. IIE, Backhuys Publishers, Brazilian Academy of Science: 477-491.
- Chambers, D., Moran, R., & Trasky, L. (2012). Chapter 5: Potential Effects of the Pebble Mine on Salmon. In *Bristol Bay's Wild Salmon Ecosystems and the Pebble Mine*. Portland, OR: Wild Salmon Center and Trout Unlimited. Retrieved from <http://www.wildsalmoncenter.org/pdf/PM-Ch5.pdf>
- Coutant, C.C. (1975): Response of Bass to Natural and artificial temperature regimes. In: R.H. Stroud and H. Clepper (eds.) *Black Bass Biology and Management*. Sport Fishing Institute, Washington, D.C. 272-285.
- Chow-fraser, P. (1991). Use of the Morphoedaphic Index to Predict Nutrient Status and Biomass in Some Canadian Lakes.
- Dankishiya, A.S., Olatunde, A.A., Balogun, J. K. (2013). ICHTHYOFAUNA COMPOSITION AND DIVERSITY OF A TROPICAL WATER SUPPLY RESERVOIR : A CASE STUDY OF LOWER USUMA RESERVOIR IN BWARI , ABUJA , NIGERIA, *1*(9), 188–203.
- Darwall, W.R.T., Vie, J.-C., (2005). Identifying important sites for conservation of freshwater biodiversity: extending the species-based approach. *Fish. Manage. Ecol.* 12, 287–293.
- Dodds, W. K., & Smith, V. H. (2016). Nitrogen , phosphorus , and eutrophication in streams, 155–164. <http://doi.org/10.5268/IW-6.2.909>
- Downing, J. A., C. Plante, and S. Lalonde. 1990. Fish production correlated with primary productivity, not the morphoedaphic index. *Canadian Journal of Fisheries and Aquatic Sciences* 47:1929–1936.
- Edward, J. B. (2013). Evaluation of the Fisheries Potentials of Egbe Reservoir , Ekiti By, 2012.
- Enderlein, R. E., & Peter, W. (1996). Chapter 2 \* - Water Quality Requirements.
- Egborge, A.B.M. (1971): The chemical hydrology of River Oshun, Western State, Nigeria. *Fresh Water Biology* 1: 257-271.

- EPA. (2012, March). What are Suspended and Bedded Sediments (SABS)?. In Water: WARSSS. Retrieved from <http://water.epa.gov/scitech/datait/tools/warsss/sabs.cfm>
- EPA. (2013). Dissolved Oxygen Depletion in Lake Erie. In Great Lakes Monitoring. Retrieved from <http://www.epa.gov/glindicators/water/oxygenb.html>
- Eyo, A. A., & Ahmed, Y. B. (2000). MANAGEMENT OF INLAND CAPTURE FISHERIES AND CHALLENGES TO FISH fisheries and the challenges it poses to fish production and suggest ways in which the management of capture fisheries could be improved so that the decline in domestic fish.
- FDF (Federal Department of Fisheries) (2003): Presidential Forum on Fisheries and Aquaculture (Status and Opportunities). Fed. Dept. of Fish Report, Abuja, Nigeria. 49p
- Hansen, M. J., Nigel, L. j., & Krueger, C. C. (2010). Natural Lakes (pp. 449–500).
- Henderson HF, Welcome RI (1974). The relationship of yield to MEI and number of fishermen in Africa Inland Fisheries. *CIFA Occasional Paper 1*, 19pp.
- Horne, A.J. and Goldman, C.R. (1994): Limnology. McGraw-Hill, Inc. New York. 576 pp.
- Ibrahim, B. U., Auta, J., & Balogun, J. K. (2009). A SURVEY OF THE ARTISANAL FISHERIES OF KONTAGORA RESERVOIR , 2(1), 47–51.
- ta, E.O. (1993): Inland fishery resources of Nigeria. FAO, CIFA occasional paper no. 20, p120
- Jackson, A. D., Harvey, H. H., & Somers, M. K. (1990). Ratios in Aquatic Sciences: Statistical Shortcomings with Mean Depth and the Morphoedaphic Index.
- Jackson, D.C. and Marmulla, G. (2001): The influence of dams on river fisheries. In: Dams, Fish and Fisheries, opportunities, challenges and conflict resolution (ed. G. Marmula) FAO Fish Tech. Pap No. 419, FAO Rome 1-44.
- Jafri, S. I. H., Mahar, M. A., Baloch, W. A., & Narejo, N. T. (2006). Trophic State Index , Morphoedaphic index and fish yield prediction in a sub-tropical lake , Manchar ( Sindh ), Pakistan, *10(2)*, 131–137.
- Jenkins RM (1982).The morphoedaphic index and reservoirs fishproduction. *Trans Amer Fish Soc*, 111: 133-140.
- Jeje, C. Y. (1997). Eleiyele reservoir by its fisheries coope, (1986), 163–170.
- Jin, S., Yan, X., Zhang, H., & Fan, W. (2015). Weight – length relationships and Fulton ’ s condition factors of skipjack tuna ( *Katsuwonus pelamis* ) in the western and central Pacific Ocean, 1–11. <http://doi.org/10.7717/peerj.758>
- Kang, B. & Wu Y. (2009): Fish and fisheries in the Upper Mekong: current assessment of the fish community, threats and conservation. *Rev Fish Biol Fisheries* DOI 10.1007/s11160-009-9114-5
- Kalff, J. (2002). Limnology: inland water ecosystems. Prentice Hall, Upper Saddle River, New Jersey.

- Lawson O.E. and O.M. Olusanya (2010): fish diversity in three tributaries of River Ore, south west, Nigeria World Journal of fish and marine science 2 (6): 524-531
- Laë, R., Lek, S., & Moreau, J. (1999). Predicting fish yield of African lakes using neural networks, *120*, 325–335.
- Langman, O. C., Hanson, P. C., Carpenter, S. R., & Hu, Y. H. (2010). Control of dissolved oxygen in northern temperate lakes over scales ranging from minutes to days, *9*, 193–202. <http://doi.org/10.3354/ab00249>
- Lenntech. (2013). Acids and Alkalis in freshwater. In Water Treatment Solutions. Retrieved from <http://www.lenntech.com/aquatic/acids-alkalis.htm>
- Levesque, J.C.(2007). First Observation on the re-established Southeast Florida recreational swordfish tournament fishery. *fla.Sci70*. 284-296
- Lizama, M., & Ambrosio, A. . (2002). CONDITION FACTOR IN NINE SPECIES OF FISH OF THE CHARACIDAE FAMILY IN THE UPPER PARANÁ RIVER FLOODPLAIN , BRAZIL, *62*(1), 113–124.
- Loftus, K. H., Ryder, R. A., Kerr, S. R., & Regier, H. A. (1974). The Morphoedaphic Index , a Fish Yield Estimator - Review and Evaluationl ' 2.
- Margalef R. (1968). Perspectives in Ecological Theory. University of Chicago Press, Chicago. 111 pp.
- Marshall, B.E., 1984. Predicting ecology and fish yields in African reservoir from preimpoundment physicochemical data. CIFA Technical Paper No 12. FAO Rome, Italy.
- Marshall, B. and M. Maes, 1994. Small water bodies and their fisheries in Southern Africa. CIFA Technical Paper No 29. FAO Rome, Italy.
- Martinez-Placioso, C. A., Sanchez, C. C. and Olvera, M. A. (1993). The Potential for Culture of the American Cichlidae with Emphasis on *Cichlas maurophthalmus*. In: Muir, J.F. and Roberts, R.J. (Eds): Recent Advances in Aquaculture. Blackwell Scientific Publications, Oxford. 208pp.
- Miller, J W (2004). Farming Nigeria's Waters; Newsletter of the Aquaculture and Inland fisheries Project of the National Special Programme for Food Security in Nigeria. Technical Note Number 5, (April), 4pp.
- Miller, R. L., Bradford, W. L., & Peters, N. E. (1988). Specific Conductance: Theoretical Considerations and Application to Analytical Quality Control. In U.S. Geological Survey Water-Supply Paper. Retrieved from <http://pubs.usgs.gov/wsp/2311/report.pdf>
- Mosa S, Regidor H (2003). AES Juramento S.A. Programa de Monitoreo Cabra Corral-Pe.as Blancas-El Tunal. Informe Anual 2003.
- Moore, W.L. (1989): NALMS management guide for lakes and reservoirs. North American Lake Management Society. Madison, WI USA. 44 pp.
- Mustapha, M. (2009). *LIMNOLOGY AND FISH ASSEMBLAGES OF OYUN RESERVOIR*,

- OFFA, NIGERIA. University of Ilorin, Nigeria. University of Ilorin.*
- Mustapha, M. K. (2009). Limnological evaluation of the fisheries potentials and productivity of a small shallow tropical African reservoir, *57*(December), 1093–1106.
- Nazeef, S., & Abubakar, U. M. (2013). Diversity and Condition Factor of Fish Species of Dadin Kowa Dam , Gombe State, Nigeria, *2012*.
- Nehemia, A., Maganira, J. D., & Rumisha, C. (2012). Length-Weight relationship and condition factor of tilapia species grown in marine and fresh water ponds, 117–124.  
<http://doi.org/10.5251/abjna.2012.3.3.117.124>
- Obasohan E.E.; J.A.O Oransaye (2006); “Biodiversity and Sustainability of Freshwater Fishes of Nigeria, FISON Proceedings 230-237.
- O., Jim-Saiki L., A. T. A. (2014). Factors Constraining Artisanal Fish Production in the Fishing Communities of Ibeju-Lekki Local Government Area of Lagos State Abstract :, *3*(13), 97–101.
- Omowumi, M. (2013). Ichthyofauna diversity of Lake Asejire : Ecological implications, *5*(10), 248–252. <http://doi.org/10.5897/IJFA13.0379>
- Oruonye, E. D. (2014). The Challenges of Fishery Resource Management Practices in Mayo Ranewo Community in Ardo Kola Local GovernmentArea (LGA), Taraba State Nigeria, *14*(3).
- Osmond, D.L., D.E. Line, J.A. Gale, R.W. Gannon, C.B. Knott, K.A. Bartenhagen, M.H. Turner, S.W. Coffey, J. Spooner, J. Wells, J.C. Walker, L.L. Hargrove, M.A. Foster, P.D. Robillard, and D.W. Lehning. (1995). Turbidity. In WATERSHEDSS: Water, Soil and Hydro-Environmental Decision Support System, <http://h2osparc.wq.ncsu.edu>. Retrieved from <http://www.water.ncsu.edu/watershedss/info/turbid.html>
- Oyewo, D. S. (2015). *A SURVEY OF FISH SPECIES DIVERSITY AND ABUNDANCE IN DOGON RUWA WATER BODY OF KAMUKU NATIONAL PARK, BIRNIN GWARI, KADUNA STATE, NIGERIA*. AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA.
- Paytan, A. (2006). Major Ions, Conservative Elements and Dissolved Gases in Seawater (lecture 4). In Marine Chemistry. Retrieved from [http://ocean.stanford.edu/courses/bomc/chem/lecture\\_04.pdf](http://ocean.stanford.edu/courses/bomc/chem/lecture_04.pdf)
- Perera, A. E. . (2003). A Comparative Study of Potential Fish Yields and Productivity Levels of Devalahandiya and Wijayakatupotha Reservoirs in Puttalam District . by.
- Perlman, H. (2013). Water Properties: Temperature. In The USGS Water Science School . Retrieved from <http://ga.water.usgs.gov/edu/temperature.html>
- Pielou E. C. (1969). An Introduction to Mathematical Ecology. Jonn Wiley and Sons, New York.
- Ponce, V. M. (2014). Total dissolved solids (TDS) based on electrical conductivity (EC). In Online Salinity Calculator. Retrieved from <http://ponce.sdsu.edu/onlinesalinity.php>

- Pratt, K. W. (2013). Answer: What is the difference between distilled water and deionized water (DI water)?. In Research Gate. Retrieved from [http://www.researchgate.net/post/What\\_is\\_the\\_difference\\_between\\_distilled\\_water\\_and\\_deionized\\_water\\_DI\\_water2](http://www.researchgate.net/post/What_is_the_difference_between_distilled_water_and_deionized_water_DI_water2)
- Quarcoopome, T., & Amevenku, F. Y. K. (2008). Fisheries and Limnology of Two Reservoirs in Northern Ghana, *12*.
- Radke, L. (2006). pH of Coastal Waterways. In Oz Coasts. Retrieved from [http://www.ozcoasts.gov.au/indicators/ph\\_coastal\\_waterways.jsp](http://www.ozcoasts.gov.au/indicators/ph_coastal_waterways.jsp)
- Reed W, Birchard J, Hopson AJ, Jenness J, Yaro I (1967). *Fish and Fisheries of Northern, Nigeria*. Ministry of Agriculture, Zaria, Northern Nigeria. 226pp.
- Ryder, R. A. (1982). The Morphoedaphic Index--Use , Abuse , and Fundamental Concepts.
- Ryder, R.A., 1965. A method for estimating the potential fish production of North temperate lakes. *Trans. Am. Fish. Soc.*, 94: 214-218.
- Salihi, A. (2009). "Hydropower Development at Tiga and Challawa Gorge Dams, Kano State, Nigeria" (PDF). International Network on Small Hydro Power (IN-SHP). Archived from the original (PDF) on 26 July 2011. Retrieved 2009-10-02.
- Scannell, P. W., & Jacobs, L. L. (2001, June). Technical Report: No. 01-06 Effects of Total Dissolved Solids on Aquatic Organisms. In Alaska Department of Fish and Game: Division of Habitat and Restoration. Retrieved from [http://www.adfg.alaska.gov/static/home/library/pdfs/habitat/01\\_06.pdf](http://www.adfg.alaska.gov/static/home/library/pdfs/habitat/01_06.pdf)
- Seiyaboh, E. I., Izah, S. C., & Okogbue, B. C. (2016). Seasonal Variation in Length-Weight Relationship and Condition Factor of Five Fish Species from Kolo Creek , Niger Delta, (March 2017). <http://doi.org/10.15580/GJAS.2016.11.121916216>
- Shannon E. C. and Wiener W. (1963). *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, 117 pp.
- Sommer, K., & Spitzer, P. (2004, April). Session H: Ocean Salinity (Powerpoint). In Plenary lecture: WMO-BIPM WS Geneva 30 March-1 April. Retrieved from [http://www.bipm.org/ws/BIPM/WMO-BIPM/Allowed/Plenary\\_lectures/04.04-Session\\_H-Intro-Sommer.pdf](http://www.bipm.org/ws/BIPM/WMO-BIPM/Allowed/Plenary_lectures/04.04-Session_H-Intro-Sommer.pdf)
- Sriyasak, P., Chitmanat, C., & Whangchai, N. (2015). Effect of water de-stratification on dissolved oxygen and ammonia in tilapia ponds in Northern Thailand. *International Aquatic Research*, 7(4), 287–299. <http://doi.org/10.1007/s40071-015-0113-y>
- Sun, W., & Boyd, C. E. (2013). Phosphorus and Nitrogen Budgets for Inland , Saline Water Shrimp Ponds in Alabama, 4(1), 1–5. <http://doi.org/10.4172/2150-3508.1000080>
- Sugunan, V.V. (1995). Reservoir fisheries of India. FAO Fish Tech. Pap. No. 345. Rome, Italy.
- SWRCB. (2002). Electrical Conductivity/Salinity Fact Sheet . In *The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment State Water Resources*

- Control Board. Retrieved from [http://www.swrcb.ca.gov/water\\_issues/programs/swamp/docs/cwt/guidance/3130en.pdf](http://www.swrcb.ca.gov/water_issues/programs/swamp/docs/cwt/guidance/3130en.pdf)
- Talling, J. F. (2010). pH , the CO<sub>2</sub> system and freshwater science, 133–146. <http://doi.org/10.1608/FRJ-3.2.156>
- Thompson, K., AWWA Research Foundation, WaterReuse Foundation, & Water Quality Association. (2006). Characterizing and Managing Salinity Loadings in Reclaimed Water Systems. N.p.: American Water Works Association.
- Tonn, W. M. 1990. Climate change and fish communities: a conceptual framework. *Transactions of the American Fisheries Society* 119:337–352
- United State Environmental Protection Agency (U.S.E.P.A) (1976): Quality criteria for Water. Report No. EAP-440/9-76-023. Washington, D.C. 501 pp.
- Utah State University . (2013). pH. In *Utah Water Quality*. Retrieved from <http://extension.usu.edu/waterquality/htm/whats-in-your-water/ph>
- Uyigue, E.(2009) Society for Water and Public Health Protection. "The Efficiency and Impacts of Dams: A Case Study of the Challawa Gorge Dam" (PDF). Netherlands Society for Nature and Environment. Archived from the original (PDF) on 2011-07-17. Retrieved 2009-10-02.
- Ville, D. (2011). A survey of the lakes of the English Lake District :
- Walters, C. J., and S. J. D. Martell. 2004. *Fisheries ecology and management*. Princeton University Press, Princeton, New Jersey.
- Webster, I., Atkinson, I., & Radke, L. (2013). Salinity. In *Oz Coasts*. Retrieved from <http://www.ozcoasts.gov.au/indicators/salinity.jsp>
- Wetzel, R.G. (1999): Biodiversity and shifting energetic stability within freshwater ecosystems. *Arch. Hydrobiol. Spec. Issues Advances in Limnology* 54: 19-32.
- Wetzel, R. G. 2001. *Limnology: lake and river ecosystems*, 3rd edition. Academic Press, San Diego, California.
- Willis, D. (2006). Winter Oxygen and Your Fish. In *Pond Boss*. Retrieved from <http://www.sdstate.edu/nrm/outreach/pond/upload/Winter-Oxygen-and-Your-Fish-Sep-Oct-2006.pdf>
- Wurts, W. A., & Durborow, R. M. (1992). Interactions of pH, Carbon Dioxide, Alkalinity and Hardness in Fish Ponds. In *Southern Regional Aquaculture Center*. Retrieved from <https://srac.tamu.edu/index.cfm/event/getFactSheet/whichfactsheet/112/>

