

**A STUDY ON FISH SPECIES DIVERSITY AND
POPULATION DYNAMICS IN JAKARA RESERVOIR,
KANO STATE, NIGERIA**

By

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**BEING A DISSERTATION SUBMITTED TO THE
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SCIENCE (M.Sc.) IN FISHERIES AND AQUACULTURE.**

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September, 2019.

DECLARATION

I declare that the work in this dissertation entitled “A Study on Fish Species Diversity and Population Dynamics in Jakara Reservoir, Kano State Nigeria” has been conducted by me in the Department of Biological Sciences, Faculty of Life Sciences, Bayero University Kano, under the supervision of Prof. Idris Ado Yola. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this research had been previously presented for another degree at Bayero University Kano or any other institution.

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CERTIFICATION

This is to certify that the research work for this dissertation “A Study on Fish Species Diversity and Population Dynamics in Jakara Reservoir, Kano State Nigeria” (Zainab Dalha Abdullahi SPS/16/MAB/00019) were carried out under my supervision .

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ABSTRACT

Fish species diversity and population parameters from three different sites (A, B and C) of Jakara Reservoir were studied from February 2018 to July 2018. Low Shannon-weiner index (0.77-1.33) and Simpsons index of diversity (0.411-0.701) indicates that the reservoir was not diverse. Five (5) species from two (2) families were identified during the period of study. The species identified were *Clarias anguillaris*, and *Clarias gariepinus*, belonging to family Claridae and *Oreochromis niloticus*, *Hemichromis bimaculatus* and *Tilapia zillii* belonging to family Chichlidae. The family Chichlidae has more species appearance with 87.32% with *O.niloticus* dominating the catches 60.34%, while the least species appearance with 12.68% was Claridae. Site C has the highest fish frequency (49.6%) while site B is the lowest (19.0%). The month of July has the highest frequency of all the fish species (21.96%), where as the fewest fish (12.37%) were caught in February. In terms of population dynamics, FAO and ICLARM Stock Assessment Tools (FISAT) was used to analyse growth, recruitment and mortality parameters on length based data. *C.anguillaris* was not analysed due to low data which does not behave well in the software. The species were small in size especially chichlidae with higher growth rate. Mortality was low and more of natural factors. The recruitment of all the species was found throughout the year with major peak in June. By using Pauly's exploitation rate of 0.5 and values obtained from relative yield and relative biomass per recruit (E_{Max} , $E_{0.1}$ and $E_{0.5}$), Jakara Dam fishes were not over exploited and economic target was not achieved. The growth pattern of the species was negatively allometric with b values of 1.14 - 1.83.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The ecosystem services of freshwater aquaculture have the capacity to generate significant economic returns, support recreational activities with substantial societal benefits, and play an important role in global food production (Pitcher, 1999; Ross *et al.*, 2008). Global freshwater fish aquaculture production in 2009 exceeded 73 million tones, worth approximately \$US 61 billion (FAO, 2014). Fish is widely consumed by people throughout the globe as staple food with a rich source of proteins for health benefits (Mayank *et al.*, 2017). Olusola and Arawomo (2008) stated that it contributes as much as 17% of the world's animal protein. Inland fisheries play an important role in the provision of protein to Nigerians with a high population of about 178.5 million people (FDF, 2008), especially when imported, fish is becoming too expensive for low income earners as observed by Olusola and Arawomo (2008).

Apart from being used as food, it contributes to the country's GDP as well as employment generation (Cadima, 2003). The nutritive and medicinal importance of fish has been recognized since from ancient time to date (Ravindra *et al.*, 2014). Fish is of great benefit for cardio-vascular disease patients due to its Omega- 3 polyunsaturated fatty acid component (Dan-kishiya, 2013). Looking at all this and being the cheapest source of animal protein to human, fish need to be manage and conserve in reservoirs for human benefit (Ibrahim *et al.*, 2009). Their rate of exploitation must balance their renewability capacity since they are limited but renewable (Udoh *et al.*, 2013). This requires detail

knowledge of the species diversity and composition in the water bodies (Abiodun & John, 2017), as well as population dynamics.

In Nigeria, fisheries resources are on the decline due to over exploitation and inadequate management of the coastal waters. For sustainability of these resources, an adequate knowledge of biodiversity and population dynamics of the water bodies must be understood and vigorously pursued (Lawson & Olusanya, 2010). Knowledge of fish biodiversity and population dynamics is important and necessary in fishery biology in order to determine the status of fish stock and manage fishery resources (Dwivedi, 2012; Rizvi *et al.*, 2010). It is the basis for understanding changing fishery patterns and issues such as habitat destruction, predation and optimal harvesting rates (Gupta *et al.*, 2015). Biodiversity is a measure of the members of species that make up a biological community and is considered to be one of the most important aspects of community organization and structure. Species richness and relative abundance describe key elements of biodiversity. The former is the number of different species in a given area, which is the fundamental unit in which to assess the homogeneity of an environment, it is commonly used in conservation studies to determine the sensitivity of ecosystems and their resident species, while the latter describes how common or rare a species is, relative to other species in a given community (Lawson & Olusanya, 2010).

Banks *et al.* (1967) identified and described about 139 species of fish in River Niger within the then proposed Kainji Reservoir Basin. Reed *et al.* (1967) reported about 160 species within the then Northern Region of Nigeria. Since then, numerous studies have been undertaken on Lake Kainji and other freshwater bodies leading to the description of many species (Chude, 1979; Ita & Pandogari 1987). According to Obasohan and

Oronsaye (2006), Welman (1984) identified 181 species of fish from the major river systems and Lakes of Nigeria, including some estuarine and marine fish species which are frequent in the rivers.

Population dynamics on the other hand describes the ways in which a given population grows and shrinks over time, It covers aspect of birth, growth, and mortality (Mayank *et al.*, 2017).

FDF (2008) estimated the fish production from small water bodies in Africa as two million tonnes annually and argued that it could be considerably more if production enhancement fishing systems were applied, an approach to which small water bodies are particularly well suited.

1.2 Statement of the Research Problem

Fishing activities have direct influences on fish communities. Urbanization is responsible for increase in fish demand, which entails an increased pressure on the already overexploited stocks, especially in tropical reservoir fisheries (World Bank, 1992). The world per capita fish consumption is reported to have increased from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 (Wehye *et al.*, 2017). Driving fisheries resources to extinction (Abeer *et al.*, 2017). It is therefore imperative that fishery resources should be properly managed to sustain its benefit to the future generations (Indira & Pugazhendy, 2016).

1.3 Justification

Overall aim of fisheries management study is to give decision-makers insight of what is happening in a water body and to give advice on the optimum exploitation of aquatic living resources especially freshwater commercial fishes. This can only be achieved through considerable knowledge of species diversity and population parameters (Abeer *et al.*, 2017). The species diversity, asymptotic length (L_{∞}), growth coefficient (K), instantaneous rates of natural (M), fishing (F) and total mortality (Z), recruitment, stock assessment, condition factor and length-weight relationship are the parameters of interest for this research. Understanding these parameters is essential to meet one of the main objectives of fishery management studies that of maximizing yield to fisheries, while safeguarding the long-term viability of populations and ecosystem (Jennings *et al.*, 2000). These parameters also provide tools for scientific interpretation of population dynamics as well as formulation of conservation policies (Sajan *et al.*, 2015), and management strategies.

1.4 Aim

The aim of this work is to study fish species diversity and population dynamics in Jakara Reservoir, Kano state, Nigeria.

1.5 Objectives of the Study

The objectives of the study were to:

- 1) Identify different fish species in Jakara Reservoir.
- 2) Measure length and weight of the identified species.
- 3) Analyse population rate function
- 4) Assess fish stock in the Reservoir.

1.6 Research Hypothesis

H_{01} : Jakara Reservoir is not diverse in terms of fish species.

H_{02} : There are no significant differences in weight and length of the fish species.

H_{03} : There are no changes in the population rate functions in the Reservoir.

H_{04} : Fish stocks in the Reservoir are not overexploited.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Freshwater resources are very precious for life on earth. The number of reservoirs has significantly increased in last few years. The aquatic ecosystem is important and it has large number of economically important animals especially fish which is an important source of food. The development of fisheries in these fresh water resources needs to be increased through the scientific development (Ravindra *et al.*, 2014).

Reservoirs are created usually for purposes such as to generate electricity, irrigation or domestic usage. It forms one of the most important sources of large number of living aquatic animals, which are economically important for nature as well as for human beings as food (Ravindra *et al.*, 2014). The Fish yield from Reservoirs may constitute a substantial contribution to a country's total domestic fish production (Dan-kishiya *et al.*, 2012) but, the effectiveness of their contributions depends largely on adequate fish assemblages and proper management of the Reservoir fisheries (Mustapha, 2008).

Nigeria has over 12.5 million hectares of water reservoirs, lakes, ponds and rivers capable of providing over 980,000 million metric tons of fish annually (Ita, 1985). This makes the country to offer the largest market for fisheries products in Africa (Adedeji & Okocha, 2011). Over 80% of reservoirs that are in existence are located in the northern region which produced up to 410, 000 metric tons of fish annually (Imam *et al.*, 2010). Despite all this, statistical surveys shows that the demand for fish in the country exceeds supply,

and also, the domestic production is still very low, considering the increasing human population (Ibrahim *et al.*, 2009), pollution and poor management policies and strategies.

2.2 Fish Species Diversity

Biodiversity is the term used to describe the total variety of living organisms (plants, animals, fungi and microbes) that exist on our planet. It is the totality of genes, species and ecosystems in a region (Oribhabor, 2016). In another term, Biodiversity is the variation in the genetics and life forms of populations, species, communities and ecosystems (Hiddink, *et al.*, 2006). Species diversity encompasses variety of species within a geographical area (Abiodun & John, 2017). Biological diversity is a broader term that can incorporate functional group diversity, number of trophic levels or relative species abundance. The diversity indices of Simpson and Shannon incorporate species abundances in addition to species richness and are intended to reflect the likelihood that two individuals taken at random are of the same species. However, they tend to de-emphasize uncommon species (Brown *et al.*, 2007). These indices are given formulas as

Shannon-Wiener diversity index (H')

$$H' = -\sum [(n_i/N) \times \ln(n_i/N)] \text{ (Shannon and Wiener, 1949)}$$

Where, H' = Shannon-Wiener index, n_i = Number of individuals of each specie and N = Total number of individuals for the site or month.

Simpson's Index (D):

$$D = \sum n_i (n_i - 1) / N (N - 1) \text{ Simpson (1949)}$$

This leads to calculation of Simpson's index of diversity (heterogeneity index) = (1-D) Lande (1996).

Where, D = Simpson's Index, n_i = Number of individuals of each specie and N = Total number of individuals for the site or month.

Fishes can be found in nearly all aquatic environments. Fish exhibit greater species diversity than any other group of vertebrates, with over 32,000 different species worldwide, they exhibit enormous diversity in their morphology, in the habitats they occupy, and in their biology. Unlike the other commonly recognized vertebrates, fish are heterogeneous assemblage (Forese & Pauly, 1998) that occupied an extra-ordinary array of habitats. They can be found in seasonal streams, rivers, reservoirs, tiny desert springs, and the vast reaches of open oceans, deep oceanic trenches, cold mountain streams, saline coastal embayment, or nearly endless list of aquatic environments (Moyle & Cech, 1996). A high genetic diversity within a fish population may protect it against environmental stressors (e. g., climate change, pollutants) and the spread of diseases (Hiddink *et al.*, 2006).

Nigerian freshwaters occupies about 3.4% of the total area, harboring an estimated value of about 230 fish species, indicating the potential and fish diversity in the rivers, lakes and reservoirs in the Country (Ita, 1993). The most important fishes in terms of species diversity are the teleosts (Young 1962; Parker & Haswell, 1964).

The overall contribution of the freshwater species to the total domestic fish production in Nigeria was estimated at 248,000 metric tons representing about 47.8% of the total fish catches mainly by artisanal fishermen all over the rivers, lakes and reservoirs (Ita, 1993).

Investigations into the biodiversity of fish species of Nigerian inland water bodies have been carried out by various scientists. These include the works of Banks *et al.* (1966),

Reed *et al.* (1967), Awachie (1976), Ita *et al.* (1982), Welman (1984), Akinyemi *et al.* (1985), Ita and Pandogari (1987), Chidi (1993), Balogun (2005) and Ibrahim *et al.* (2009).

Recently, Abiodun and John (2017) Studied on fish and fisheries of the Lower Niger River at Idah in Kogi State, were forty-two (42) species of fish belonging to 18 families were recorded with *Hyperopterus bebe* (10.61%) dominating the catches. Also, in terms of species diversity, the family Mormyridae had the highest (18.29%) with seven species including *Hyperopterus bebe*. The diversity, length-weight relationship and condition factor of fish species of Thomas Reservoir, Dambatta, Kano State, by Nafiu *et al.* (2017) revealed a total of 313 fishes comprising of 7 families and 11 species. Family cichlidae was predominant (36.7%) represented by *T. zillii* (21.7%) and *O. niloticus* (15.0%). Family Claridae was the second highest in abundance with 24.7% represented by *C. garipienus* (8.9%), *C. anguillaris* (8.9%) and *Heterobranchus sp.* (6.7%) while Protopteridae represented by *Protopterus sp.* was the least with 2.8%. Olopade and Rufai (2014) determined status of the family Cichlidae in Oyan Dam, Nigeria, during the wet and dry seasons of 2011; species recorded include *Sarotherodon galilaeus* (42.60%), *O. niloticus* (17.92%), *T. zillii* (25.41%), *H. fasciatus* (10.61%) and *T. mariae* (3.48%). The diversity indexes showed that the diversity of Cichlids was lower in the two sampling sites observed in Oyan Dam. Arome and Ugondo (2014) investigated the fish species diversity and abundance of Gubi dam in Bauchi State, Nigeria, were they recorded low species richness in the Dam with a total of 18 species of fish belonging to six families. The most abundant family was Cichlidae (61.51%) with the species *S. galilaeus* being the most abundant (34.88%) while the family Mochokidae was least abundant (1.45%) and is

represented by only one species. Dan-kishiya *et al.* (2013) Studied on Ichthyofauna composition and diversity of Lower Usuma Reservoir from July 2009 to April 2011 were a total of 2698 fishes belonging to 11 species and 5 families were encountered. The fish families Cichlidae (78.84%), Cyprinidae (16.31%), Clariidae (3.93%), Bagridae (0.78%) and Mormyridae (0.15%) constituted the fishery resources.

2.2.1 Species Richness

The ability to measure biodiversity is critically important, given the soaring rates of species extinction and human alteration of natural habitats. Perhaps the simplest and most frequently used measure of biological diversity is species richness, the number of species per unit area. A vast amount of ecological research has been undertaken using species richness as a measure to understand what affects, and what is affected by, biodiversity. At the small scale, species richness is generally used as a measure of diversity within a single ecological community, habitat or micro-habitat, although the definition of small depends on the species in question (Brown *et al.*, 2007).

Species richness measures are typically separated into measures of α , β and γ diversity (Whittaker, 1972). α diversity (also referred to as local or site diversity) is nearly synonymous with small-scale species richness; it is measured at the local scale and consists of a count of species within a relatively homogeneous area. From a practical standpoint, the determination of what is local and homogeneous depends on the size of the organisms being studied, and could range from a 1m² to 1000m² sample site. β diversity is the change in species composition from one site to the next along a gradient, also referred to as species turnover. Unlike α diversity, which provides information about diversity at a local site, β diversity provides information about how diversity changes

along environmental gradients. Finally, γ diversity is a measure of the diversity across habitats or community types within a landscape or region. While α diversity usually refers to a homogeneous area, γ diversity includes the various habitats, conditions and communities. Because γ diversity is defined as the product of α and β diversity, it takes into account both the local richness (α diversity) of sites within the region as well as the rate of change in richness between those sites (β diversity), to give a measure of richness that reflects diversity across the communities and conditions within the geographic region (Brown *et al.*, 2007).

2.2.2 Relative Species Abundance

Relative abundance refers to how common or rare a species is, relative to other species in a given location or community (Hubell, 2001; McGill *et al.*, 2007). It is a fundamental description of an ecological community (Gaston & Spicer, 1998). Although estimating the species relative abundance is basic, yet it represents informative data for ecologists and conservation biologists (Gaston 2003). Ecologists use data of species relative abundance to infer information about the mode of interaction and type of relationship among different species in a given community (Ferrier & Guisan, 2006). Moreover, species relative abundances data is used to perform population viability analysis (Possingham, *et al.*, 2001), and estimate ecological disturbance (Regan, *et al.*, 2003). In conservation biology and management, information on relative abundances is of great importance, such as to study the impact of habitat disturbances, like fragmentation. It is well known that disturbed and fragmented habitats are usually dominated by a very few species compared to the undisturbed sites (Guisan, *et al.*, 1999)

Relative species abundance and species richness describe key elements of biodiversity (Hubell, 2001). The relative abundance is calculated as the number of organisms of a particular kind as a percentage of the total number of organisms of a given area or community; the number of fish of a particular species as a percentage of the total fish population of a given area (Krohne, 2001).

Relative species abundance %:

$$(n/N) \times 100$$

Where, n = Number of species from each catch and N = Total number of species from the total catch.

2.2.2 Factors Affecting Fish Diversity

The diversity of fishes mainly depends upon the biotic and abiotic factors and types of ecosystem (Nanda & Tiwari, 2001). Organisms within a community are affected by trophic diversity, the abundance of some organisms that are specialized to feed at certain trophic levels and on specific organisms are affected when there are changes in the availability of their specific food (Ogutu-ohwayo, 2005). The work of Omowumi (2013) identify the ecological implication of the stock diversity and abundance in Lake Asejire, Osun state Nigeria. Age of water body, mean depth, water level fluctuation and morphometric features have great ecological implications.

The biodiversity of the Nigerian aquatic ecosystems is increasingly being destroyed or depleted by persistent threat of aquatic pollution resulting from intense human activities such as indiscriminate use of fertilizers and pesticides in agriculture; industrialization; urbanization; pressure due to rapid population growth; malutilization and

mismanagement of natural aquatic resources; dam, road and bridge construction; irrigation; draining and filling of wetlands (Oribhabor, 2016). Fish diversity is declining rapidly each day due to unending anthropogenic stress (Ravindra *et al.*, 2014), changes occur in fish diversity in the course of development of a lake after impoundment of rivers as a result of changes in the physical environment which affect water quality and consequently the type and population of food organisms that evolve (Omowumi, 2013). Exploitation, that is fishing, is a major tool responsible for alterations in the diversities of resources in a community (Omowumi, 2013).

Economic activities in fisheries sector have been unregulated and therefore haphazard with adverse consequences on the ichthyofauna especially the biological important endemic species. Though most Nigerian states have fisheries decree, but, these laws and regulations are not effectively enforced (Obasohan & Oronsaye, 2006).

Drought and predation are two outstanding natural problems. Bukar and Gubio (1985) reported ichthyofauna biodiversity changes, resulting from drought in Lake Chad, Nigeria and noted that the reduction in Lake water level resulted in increased temperatures, nutrients, carbon dioxide, hydrogen sulphide, pH, competition, death and decomposition. Some of the lake fish's species were succeeded by *Clarias gariepinus*. Predation was a serious biodiversity problem as the food web involved various taxa. Olatunde (1977) reported that the populations of *Eutropius niloticus* and *Schilbe mystus*, two important fish species in Lake Kainji, were preyed upon by the Nile perch (*Lates nilotcus*).

2.2.3 Jakara Reservoir Fish Diversity

Jakara Reservoir is one of the important Reservoirs in Kano State for fish production and employment generation. Unfortunately, the Dam is polluted due to discharge of pollutant from Domestic sources, city, abattoir, Bompai industrial area, and other industrial effluent (Volume, 2010), this have great consequences on its fish diversity. According to the fishermen, apart from the identified species, Carp and some other species exist before, but due to poor management, excessive exploitation and lack of government intervention, they no longer exist. Studies on Jakara Dam fish species were documented by different authors; Length-weight relationship and condition factor of four fish species i.e. *T.zilli*, *O.niloticus*, *H.bimaculatus* and *C.gariepinus* from January to December, 2009 by Imam *et al.* (2010) and Aspect of physicochemical conditions and the fish biology by Inuwa (2007) among others.

2.3 Population Dynamics

A population is a group of organisms of the same species that are alive in a defined area at a given time (Wotton, 1998). Population dynamics is the changes in the number of individuals in a population or the vital rates of a population over time (Indira & Pugazhendy, 2016). Population dynamics are the processes responsible for changes in abundance or biomass of a population through time and are a subset of possible population parameters. Recruitment, growth, and mortality rates are the primary population dynamics (often termed rate functions) influencing the harvestable segment of a fish population (Brown & Guy, 2007).

Estimates of population dynamics can provide greater insight into fish populations than can indices, which are a static portrayal of the population. Estimates of population

dynamics can indicate how a population arrived at its current state and how it might change in the future (Renjithkumar, 2014). A population assessment might focus on determining whether the size of a population is relatively constant, increasing, or decreasing, for which one would need population abundance data and age data to calculate birth and death rates (Renjithkumar, 2014). The major role of the population dynamic study in regulating populations of fish is essential to a general understanding of the ecology including population grows and shrinks over time, as controlled by birth, death, emigration or immigration and to determine sustainable yields (Indira & Pugazhendy, 2016).

Stock assessment of tropical fish resources has gained momentum in the last one and a half decade mainly through the works of Pauly (1984). The introduction of special software for fish stock assessment in particular those based on length frequency data such as LFSA (Sparre & Venema, 1989), COMPLEAT ELEFAN (Gayanilo *et al.*, 1996) and FISAT (Gayanilo *et al.*, 1996) has also contributed to the rapid development of stock assessment studies on tropical fish stocks (Indira & Pugazhendy, 2016).

Studies on fish population dynamics include that of Wehye and Amponsah (2017) who evaluated some population parameters of *Galeoides decadactylus* within Liberia's coastal waters and found Von Bertalanffy at asymptotic length (L_{∞}) = 54.08 cm, growth rate (K) = 0.19/year, the longevity (Tmax) = 15.8 years, theoretical age at birth (t_0) = -0.75 years and growth performance index (Φ') = 2.745. Mortality parameters were calculated as total mortality rate (Z) = 0.91/year, natural mortality rate (M) = 0.49/year and fishing mortality rate (F) = 0.42/year. The exploitation rate (E) and maximum exploitation rate (Emax) were 0.46 and 0.45 respectively. Mayank *et al.* (2017) determined the population

structure of *C. mrigala* from the Yamuna River at Allahabad and recorded the asymptotic length (L_{∞}) at 99.8cm and growth coefficient (K) at 1.34/year. The total mortality (Z), fishing mortality (F) and natural mortality (M) were estimated as 4.01/year, 0.786/year and 3.226/year, respectively. Exploitation rate (E) and exploitation ratio (U) were found 0.8044/year and 0.7898/year respectively . Bawole *et al.*, (2017) studied the relationship between the rate of exploitation of *Plectropomus maculatus* and *P. oligocanthus* and their biological attributes (growth and mortality) from Cenderawasih Bay National Park (CBNP), the results showed that *Plectropomus maculatus* and *P. oligocanthus* were in the size category of actively productive spawning phase. *P. maculatus* reached a maximum length (L_{∞}) of 48.4cm and growth rate (K) of 0.34/year. *P. oligocanthus* was capable of reaching L_{∞} of 48.2cm and K of 0.66/year. Estimation of total mortality (Z) for *P. maculatus* was 0.988/year and *P. Oligocanthus* was 2.056/year, fishing mortality (F) for *P. maculatus* and *P. oligocanthus* were 0.564/year and 0.399/year respectively. The exploitation rate (E) of *P. maculatus* was 0.570, and *P. oligocanthus* was 0.681. Feu (2004) estimated the length-weight relationship, age at length zero (t_0), growth coefficient (K), asymptotic length (L_{∞}) and rates of natural (M) and total mortality (Z) of the six main commercial species of Lake Kainji, Nigeria, For four of the commercial species, the estimate of K was around 0.5/year, whilst L_{∞} was approximately 50 cm. *Lates niloticus* had the lowest value of K (0.25 year/) and the largest L_{∞} (159 cm). *Oreochromis niloticus* had a K=0.25/year and L_{∞} =53 cm. Natural mortality was the lowest for *L. niloticus* (M=0.49/year) and fishing mortality was highest for *Chrysichthys niloticus* (F=4.3/ year). Gabr and Mal (2017) evaluated the current stock status of the lizardfish *Saurida tumbil* in

Jizan fisheries, growth parameters, mortality coefficients and size at first capture were determined, were the result shows that the stock of *Saurida tumbil* in Jizan fisheries is currently overexploited. Indira and Pugazhendy, (2016) investigated the population dynamics of jewel Cichlid *Hemichromis bimaculatus* of Crystal Aquarium, Chennai from November, 2010 to May, 2012. Were they found that Males were significantly longer than females at the later stage of maturity, but during the initial stage of maturity, females were larger than males. Mortality was less and more observed in males. Niamaimandi *et al.* (2015) analyzed the population dynamics parameters of *Scomberomorus commerson* in Bushehr area waters of Iran between October 2011 and September 2012 were the result indicated an overfishing of *Scomberomorus commerson*, especially smaller species. The age and growth determination and population dynamics of flathead grey mullet, *Mugil cephalus* collected from Parangipettai waters during January 2004 – December 2005 were studied by Murugan *et al.* (2014) who recorded excessive fishing pressure on male species. Udoh *et al.* (2013) studies the population dynamics of *Periophthalmus barbarus* in the Imo River Estuary, southeast Nigeria, the results indicated that the fishery is highly exploited with current exploitation ratio, $E_{cur} = 0.79 > E_{max} = 0.644 > E_{opt} = 0.5$ which suggests stock over-exploitation. An investigative study was carried-out on management indicators and growth performance index of *T. zillii* in a tropical coastal estuary for twenty-four consecutive months using length-weight data by Abdul *et al.* (2012) with largest value obtained in December and smallest in April, length class of 24-25 cm was mostly exploited, constituting 9.92% while 36-37cm length class was the least (0.05 %) on the exploitation data. The population dynamics of Hilsa was investigated using FiSAT II software of FAO at West Bengal between June 2010 and March 2011 by Dutta *et al.*

(2012) were the average size group of *Hilsa* population was observed to be comparatively smaller than that found in the neighboring country. Dadzie *et al.* (2005) evaluated the growth characteristics of *Liza klunzingeri* (Day, 1888) in Kuwait Bay based on data collected from 1982 to 1999 were the fishery trap adversely affect recruitment and result in depression in the stocks. Tembo (2004) estimated growth parameters (L_{∞} and K) and mortality coefficients (Z, M and F) of *Engraulicypris sardella* and *Rhamphochromis* species caught in southern Lake Malawi using light attraction (kauni) fishery, relatively high K and low L_{∞} values, typical of short-lived tropical fishes, were obtained, combined with high Z, M and F estimates, these results imply low annual survival and high turnover rates.

2.3.1 Birth Rate / Recruitment

Recruitment means reaching a certain size or reproductive stage, with fisheries, recruitment usually refers to the age a fish can be caught and counted in nets. It is the process in which young fish enter the exploited fishing area and become liable to contact with the fishing gear (Gulland, 1969). It can come about through actual movement of young fish that are becoming older moving from the nursery ground into the main fishing area. Recruitment can also occur due to a change in habit; for instance where the old and young fish occur together in the same area; the very young, being pelagic, and recruiting to the exploited phase when they take up a demersal habitat during a period of their first year (Amiye & Francis, 2004).

The mean age of a fish at recruitment generally depends on the type and mesh size of the gear employed in fishing. The combined effect of recruitment and gear selection

produces the pattern of fish entry into the catch, that is, the recruitment pattern (Amiye & Francis, 2004).

Amiye and Franci, (2004) determined the recruitment of *Chrysichthys nigrodigitatus*, *Ethrnalosa fimbria*, *Eucinostomus rnelanopterus*, *Galeodes decadactylus*, *Pomadasys jubelini*, *Sarotherodon melanotheron*, *Liza grandisquamis*, *Tilapia guinensis* and *Pseudotolithus elongates* of Andoni River System, Niger Delta, Nigeria. The peak recruitment period for 54.55% of the species was between June and October while 21.27% had two peak recruitment periods including March May and May October.

2.3.2 Growth Rate

This measures the growth of individuals in length and weight. Growth is an important factor of biological production, which affects the overall production. Negative changes in growth rates may result in increased risk of predation and mortality (Fafioye & Oluajo, 2005). Growth rate is important in fisheries where the population is often measured in terms of biomass (Gupta *et al.*, 2015). It is intricately linked with mortality and recruitment rates. Growth rate influences survival and age at sexual maturity. Growth of fish is commonly indexed with various coefficients of the von Bertalanffy growth model which is widely used to describe the lifetime pattern of somatic growth of organisms, such as fish, with indeterminate growth (Ricker, 1975). Other growth models (e.g., Gompertz 1825; Richards, 1959) may be more appropriate than the von Bertalanffy model for some situations. In addition, specific growth rate (the change of the logarithm of weight or length per unit time), relative growth rate (the relative change of the weight or length per unit time), and length at age (e.g., mean length at age 3), either measured at

time of capture or back-calculated from hard structures such as otoliths, are also used to index growth.

Growth of fish is subject to natural environmental changes particularly climate. However, some problems are caused by human activities including fishing where more fish are taken than are replaced by birth and subsequent new fish recruitment and growth (Imam *et al.*, 2010).

Fish can attain either isometric growth, negative allometric growth or positive allometric growth. Isometric growth means all the body parts grow at approximately the same rate. Negative allometric growth implies the fish becomes more slender as it increase in weight while positive allometric growth implies the fish becomes relatively stouter or deeper-bodied as it increases in length (Nehemia *et al.*, 2012).

2.3.3 Length Weight Relationship

The length-weight relationship of a fish is basically a measure of its growth pattern and or age. Relationship of fishes are important in fisheries biology because they allow the estimation of the average weight of fish of a given length group by establishing a mathematical relation between the two (Abeer *et al.*, 2017). When b value is less or greater than 3, growth in the fish is allometric (Ikusemiju & Olaniyan, 1997); if the b-value is less than 3, the fish has a negative allometric growth but when it is greater than 3, it has a positive allometric growth and when it is equal to 3, the fish has isometric growth (Khairnizam & Norma-Rashid, 2002). Oniye *et al.* (2006) reported that the length-weight relationship of *Protopterus annectens* in Jachi Dam, Katsina State, showed positive correlation ($r=0.85$) in both 20 sexes, indicating an increase in weight as length

increased. The regression exponent ($b > 3$) for both sexes showed allometric growth. Thomas *et al.* (2003) stated that the isometric value of $b=3$ was for an ideal fish that maintained a three dimensional equality. Fafioye and Oluajo, (2005) reported a mean b value of 3.0072 for *Clarias gariepinus*, *Chrysichthys nigrodigitatus*, *Chrysichthys walkeri* and *Ethmalosa fimbriata* in Epe Lagoon, Lagos; this showed a nearly isometric relationship with 60% of the variation in body weight being accounted for by changes in length of the fish. Ogbe *et al.* (2006) reported a b value of 3.92 for *Bagrus bayad* from the lower Benue River which showed that the fish weight increased allometrically.

The relationship between body length and weight of fish presents great importance in fisheries biology and population dynamics where many stock assessment models require the use of length-weight parameters (Garcia, 1998). The analysis of length-weight data is aimed at describing mathematically the relationship between length and weight to enable conversion of one to another and measures the variation from the expected weight for length of individual fish (Dan-kishiya, 2013). It also helps to evaluate the condition, reproduction history, life cycle and the general health of the fish species (Pauly, 1993), in addition to growth pattern or age determination and fishery assessment (Balogun & Auta, 2001).

Study on length-weight relationship and condition factor of four fish species i.e. *T. zillii*, *O.niloticus*, *H. bimaculatus* and *C. gariepinus* from Wasai reservoir in Kano was conducted seasonally from January to December, 2009 by Imam *et al.* (2010) in which all of the species b values analysed do not reach 3 indicating negative allometric growth. Dan-kishiya, (2013) determined length-weight relationship and condition factor of *T. zilli*, *T. mariae*, *O. niloticus*, *Barbus occidentalis* and *Barilius loati* from Lower Usama

Reservoir in Abuja from July 2009 to June 2010. The results obtained showed that the growth pattern of the fishes was negatively allometric with b values range of between 1.4 and 2.3. The condition factor (K) range of between 1.06 and 2.02 was an indication that the fishes were thriving very well in the Reservoir.

2.3.4 Mortality Rate

The estimation of mortality rates is a basic requirement in fish stock assessment studies. The rate at which the numbers of a population is decreasing is the mortality. A population assessment might include an estimate of total annual mortality (i.e., the proportion of the population that dies in one year). Total annual mortality is related to total instantaneous mortality. Total instantaneous mortality can be estimated using a catch curve. The slope of the regression of \log_e (frequency) over age-groups equals the negative instantaneous mortality rate (Ricker 1975; Miranda & Bettoli, 2007). Fisheries managers frequently partition total annual mortality of sport or commercial species into two components:

Natural mortality, attributable to natural processes (e.g., old age, predation, competition, starvation, or disease) or those altered by human activities (e.g., habitat degradation or loss or population isolation) (Renjithkumar, 2014).

Fishing mortality attributable to harvest or handling by recreational or commercial fishers (Renjithkumar, 2014). Exploitation is the portion of the fishing mortality attributed to fishers who harvest what they catch. Exploitation is often considered synonymous with fishing mortality because estimation of other forms of fishing mortality, such as by catch or post release mortality is difficult. Exploitation can be calculated from an estimate of absolute abundance and a harvest estimate based on creel surveys (Malvestuto, 1996).

Fishing continuously on large sizes of fish or spawning fish stock could reduce the genetic characteristics and could change fish shape and behavior (Bawole *et al.*, 2017). The genetic diversity of the population would be likely affected thereby reducing its resilience in confronting with environmental change and variability (Vrijenhoek, 1998). Hurtado *et al.*, (2005) and Nelson (2007) noted that a population experiencing high exploitation is characterized by a change in the fish size composition, which is dominated by smaller sizes. This would significantly affect reproductive outcome since small fish size has less production potential than the large fish size (Bawole *et al.*, 2017). Large-scale of exploitation could cause structural changes in the fish. Sanchez (2000) suggests that in overfishing state of fish stock, the fish population is dominated by small sizes or young fish since fishermen tend to catch large size of fish.

Thus we have $Z = F + M$, where Z is the instantaneous rate of total mortality or the mortality coefficient or simply the total mortality rate, F is the fishing mortality coefficient and M is the natural mortality coefficient. An essential characteristic of a stock is that its population parameters remain constant throughout its area of distribution. The easiest way to describe the change in a fish stock is often to follow the fate of a cohort (Sparre & Venema, 1989). This means that all fish of a cohort are assumed to have the same age at a given time so that they all attain the recruitment age, t_r at the same time. Due to mortality there is a continuous decrease in the number of survivors. In the context of mortality rates the number of survivors from a cohort is estimated as a function of time (Indira & Pugazhendy, 2016).

2.3.5 Factors Affecting Population Dynamics

There are a number of factors which influence population change categorized into natural (such as climate change) and anthropogenic activities (Chimatiro, 2004). Natural disturbances, such as floods, droughts, fires, altered environmental conditions that are a consequence of climate change. A change in hydrographic conditions caused by global warming, together with a possible weakening of the thermohaline circulation (THC), will affect recruitment success (FAO, 1997).

Beside natural factors are anthropogenic changes, such as new fishing technologies; the fishing strategies applied by the fishermen have a considerable influence on the development of the commercially exploited fish species. The choice of an appropriate fishing strategy by individual fishermen ultimately determines the success of large-scale management strategies (FAO, 1999); regulation changes, or nonnative fish introductions (Renjithkumar, 2014).

Annual recruitment is typically the most variable factor affecting the dynamics of fish populations but can provide substantial insight into why fish populations may vary in size and structure (Gulland, 1982; Allen & Pine, 2000; Maceina & Pereira, 2007).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Study Area

Jakara Reservoir was impounded in 1976 under Audu Bako administration; it lies between latitude $12^{\circ}13'$ to $12^{\circ}10'$ N and longitude $8^{\circ}31'$ to $8^{\circ}45'$ E in Wasai, a village in Minjibir Local government area of Kano state, about 41km from the state capital (Badamasi, 2014), it spread to 2 other local governments of the state; Gezawa and Ungoggo. The population around the Reservoir is dispersed with few hamlets. The Reservoir was constructed for irrigation, recreation and wildlife conservation. It was designed to contain 54.34 million cubic meters of water with surface area of 1,659ha with altitude of 400-700M above sea level (WRECA, 1974). The maximum depth of the Dam was 14.3 metres (Ministry of Water Resources Kano State). The area in terms of geology falls within the tip end of the Basement complex adjoining the Chad formation, which is characterized by disappearing type of streams, the water body contain muddy substrata and gentle flowing, low turbidity water with rich growth of algae and macrophytes (Rabi, 2018). Heavy clay soils with high organic matter content dominate the bottom while lighter textured soils are found in the higher positions. The climate of the study area is tropical with two well-defined seasons; the dry season (November to April) and the rainy season (May to October). The heaviest rainfall occurs in July, August, and September. The Reservoir was named after Jakara River; a river that occupy a central position in Kano State, Northern part of Nigeria (Ekevwe & Bartholomew, 2015), it is characterized by a gentle flow and flows several kilometers passing through Kurmi market and Fagge quarters from where it meanders its way to the outskirts of the city before finally

streaming out into Jakara Reservoir (Ibrahim & Said, 2010). Industrial wastes from Bompai industrial area are discharged into it. Other tributaries of the Reservoir were River Getsi, River Gwagwarwa, River Rafin Malam, and River Cijaki, among others (Ekevwe & Bartholomew, 2015). The reservoir have spill way gate at Sankarawa in Gezawa local government area that allow flow of water to other channels.

3.2 Sampling Sites

Three sampling stations were established to be representative of various habitats existing within the Reservoir. The landing sites were selected based on different local governments and activities taking place in them.

Site A: Yadakunya/Bela bakin ruwa is located at Ungoggo local government area of the state. This site is located on latitude $12^{\circ}08' 49.29''\text{N}$ and longitude $8^{\circ}41' 19.40''\text{E}$, the inlets with mean depth of 1.2m. Fishing and farming were the major activities in this area.

Site B: Wasai is located in Minjibir local government area. This is located on latitude $12^{\circ}08' 27.97''\text{N}$ and longitude $8^{\circ}41' 11.98''\text{E}$, the outlets with mean depth of 2.3m. Alot of human activities were taking place due to the recreational center (Minjibir Golf Course) at the point.

Site C: Sankarawa/Dinga, Gezawa local government area. This site is located on latitude $12^{\circ}08' 35.86''\text{N}$ and longitude $8^{\circ}4' 15.84''\text{E}$, the midpoint of the Reservoir with mean depth of 7.4m. Fishing is the only activity in this locality.

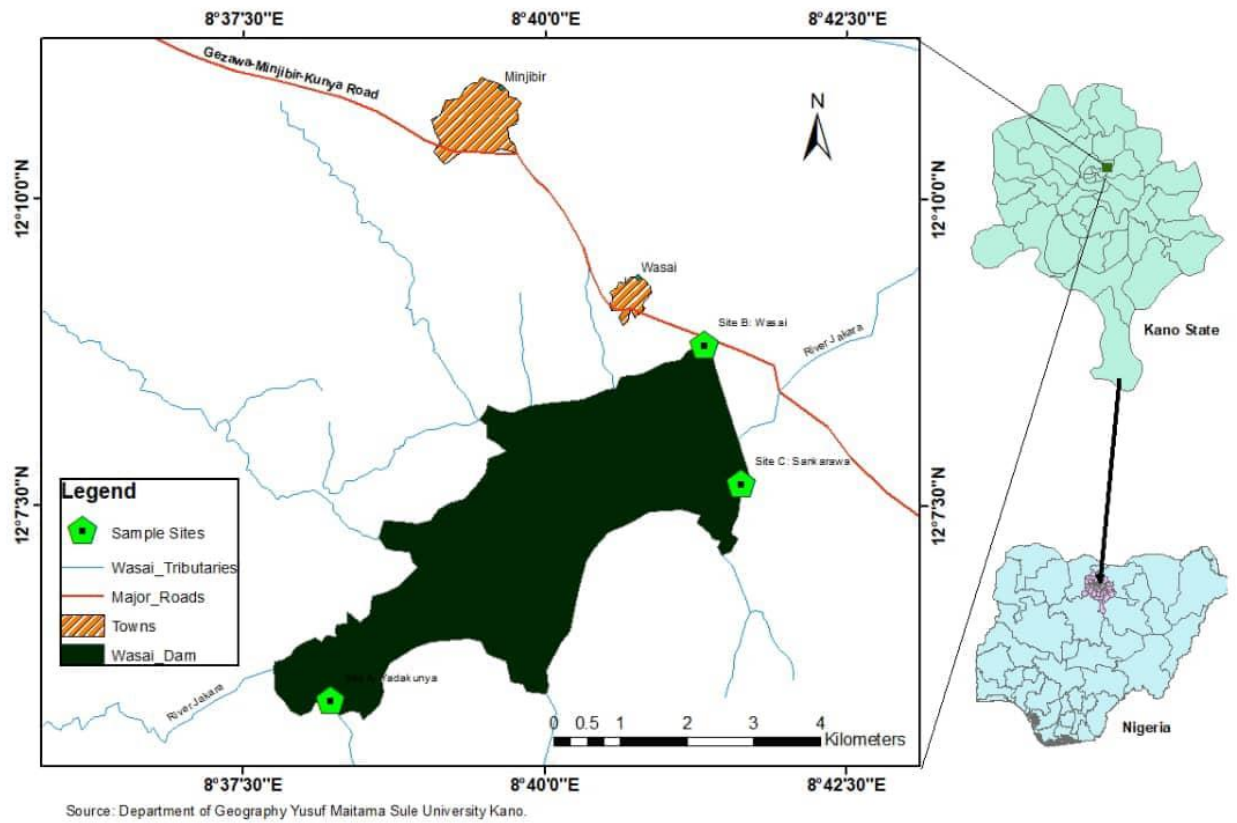


Figure: 1 Map of Jakara Reservoir showing sampling stations

3.3 Data Collection and Preservation

Monthly fish samples were collected from artisanal fishermen, for a period of six months (February- July, 2018). According to Pauly (1987) analysis of the structure of fish population requires at least 6 months data. Gears used by fisher men in this research were; seine net (mount at night and haul the following morning) and gill net (operated by many fishermen) with 20-40mm mesh size each, mostly used by adult fishermen, then, clap net of about 50cm in size and 10-20mm mesh size and some local traps (mali) used by children and aged fishermen. Sampling sites were visited monthly and on each visit, six fishermen who used the fishing gears mentioned above were randomly selected from different sampling sites and fish from their catch were sorted according to different sizes, counted and sub samples taken. The fish specimens were surrounded with iced block in a container and transported to the laboratory of Chemistry Department, Yusuf Maitama Sule University, Kano. The total length of each fish subsample (distance from the tip of the snout to the distal end of the caudal fin or tail fin) and the standard length (the distance from the tip of the snout to the end of the caudal peduncle) were measured using a meter rule to the nearest centimeter. Other morphometric structures were also measured. Weight of each fish subsample was measured to the nearest gram using Pioneer PA213C electric weighing balance of the department.

3.4 Fish Identification

Fish samples were identified to the species level using fish identification keys by Reed *et al*, (1967), where biometric features; type of the mouth, position of the mouth, barbell counts and position, dorsal and anal fin rays count, body shape, size, colour and shape of the caudal fin were examined.

3.5 Fish Species Diversity

Fish fauna diversity was analyzed using the following set of indices:

Relative species abundance %:

$$(n/N) \times 100$$

Where, n = Number of species from each catch and N = Total number of species from the total catch.

Shannon-Wiener diversity index (H')

$$H' = -\sum [(n_i/N) \times \ln(n_i/N)] \text{ (Shannon \& Wiener, 1949).}$$

Where, H' = Shannon-Wiener index, n_i = Number of individuals of each specie and N = Total number of individuals for the site or month.

Shannon-Wiener index ranges from 1.5 to 3.5 for good species diversity Magurran (2004).

Simpson's Index (D):

$$D = \sum n_i (n_i - 1) / N (N - 1) \text{ Simpson (1949)}$$

This leads to calculation of Simpson's index of diversity (heterogeneity index) = (1-D) Lande (1996).

Where, D = Simpson's Index, n_i = Number of individuals of each specie and N = Total number of individuals for the site or month.

Simpson's indexes of diversity ranges from 0-1, with 1 representing species are evenly distributed.

3.6 Growth Parameters

The growth of the fish follows the von Bertalanffy's growth function (VBGF) assumption that used asymptotic length (L_{∞}) and growth coefficient (K). These parameters were fitted in FISAT II (Gayaniilo *et al.*, 1996) for estimation.

Growth index $\varphi = \log_{10}k + 2 \log_{10} (L_{\infty})$ Pauly and Munro (1984). Where L_{∞} is the asymptotic length and K is growth curvature.

3.7 Mortality Rate

The total instantaneous mortality rate (Z) was estimated using length converted catch curve method in FiSAT II. Natural mortality rate (M) was estimated using Pauly's empirical relationship, $\text{Log } M = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log K + 0.4634 \log T$ Pauly D (1980). Fishing mortality (F) was calculated using the relationship: $F = Z - M$ Gulland (1971).

The exploitation level (E) was determined using the relationship: $E = F/Z$ Gulland (1971).

3.8 Temperature

Temperature of this research was measured in-situ using mercury in glass thermometer of Yusuf Maitama Sule University Kano.

3.9 Recruitment

The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length-frequency data as described in FISAT (Pauly & Caddy, 1985).

3.10 Relative yield per Recruit and Relative Biomass per Recruit

The relative yield-per-recruit model used was based on the Beverton and Holt (1966) model, modified by Pauly and Soriano (1986). The options assuming knife-edge selection was utilized, using probabilities of capture. L_c/L_∞ and M/K ratios were used as inputs.

Relative yield-per-recruit (Y'/R) was computed from:

$$Y'/R' = EUM/K \{1 - 3U - 3U^2 - U^3 (1 + m) (1 + 2m) (1 + 3m)\} \text{ where: } U = 1-(L_c /L_\infty);$$
$$m = (1-E)/(M/K) = (K/Z); E = F/Z$$

Relative biomass-per-recruit (B'/R) was estimated from the relationship: $B'/R = (Y'/R)/F$, while E_{Max} , $E_{0.1}$ and $E_{0.5}$ were estimated by using the first derivative of this function.

E_{max} is the exploitation rate at Maximum Sustainable Yield (MSY),

$E_{0.1}$ is the rate at Maximum Economic Yield (MEY) and

$E_{0.5}$ is the optimum exploitation rate.

3.11 Length Weight Relationship and Condition Factor (K)

The length weight relationship (LWR) was estimated using linear regression (Pauly, 1987), the techniques is incorporated in the FAO ICLARM, Stock Assessment Tool (FISAT) (Gayanilo & Pauly, 1997).

The length weight relationship was obtained from the relationship $W = aL^b$ (Gayanilo & Pauly, 1997).

$$K = W \times 100 / L^3 \text{ (Pauly,1983).}$$

Where:

W = Total Weight of fish (g)

L = Total Length of fish (cm)

a = Intercept (describe the rate of change of weight with length)

b = Slope (weight at unit length)

The values of (a) and (b) were given a logarithmic transformation according to the following formula:

$\text{Log } W = \log a + b \log L$ (Gayanilo and Pauly, 1997).

3.12 Data Analyses

The total length (TL, cm), standard length and other morphometric features of each sample were recorded, however, only total lengths was considered, using the FAO-ICLARM Stock Assessment Tools II (FiSAT II) (Gayanilo *et al.*, 2002). The length data was grouped into 2cm size classes and have 16 length-classes, as suggested by Gayanilo *et al.* (2005), for a proper implementation of the FiSAT analysis. The one-way analysis of variance (ANOVA) was adopted to measure the level of differences in fish frequency between the three sampling stations at $P > 0.05$ considered significant

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Biodiversity

Fish species frequency of Jakara Reservoir was presented in table 1, *O.niloticus* dominated the dam with 60.34% composition, followed by *T.zillii* (16.86%), *C.gariepinus* (12.15%) and *H.bimaculatus* (10.11), *C.anguillaris* has least composition of 0.53%.

Table 1: Fish Species Composition in Jakara Reservoir, Kano, Nigeria.

Species	Number (n)	% Composition
<i>C. gariepinus</i>	1375	12.15
<i>C. anguillaris</i>	60	0.53
<i>O. niloticus</i>	6827	60.34
<i>H. bimaculatus</i>	1144	10.11
<i>T. zillii</i>	1908	16.86
Total (N)	11314	100

Mean frequency of fish species in Jakara Reservoir, based on different sampling stations was presented in table 2. There is no significant different with p-value >0.05 For *C.gariepinus*, *C.anguillaris* and *H.bimaculatus* in all the sampling sites. *O.niloticus* shows an extremely significant difference in both the sampling sites and *T.zillii* shows significant difference only in site C.

Table 2: Mean Frequency of Fish Species in Jakara Reservoir, based on different Sampling Sites.

	Site A	Site B	Site C	P-value	Remark
<i>C.gariepinus</i>	81.5 ± 55 ^a	30.83 ± 42 ^a	116.83 ± 95 ^a	0.13	Not significant
<i>C.anguillaris</i>	2.33 ± 4.1 ^a	2.5 ± 3 ^a	5.16 ± 7.1 ^a	0.56	Not significant
<i>O.niloticus</i>	365.67 ± 71 ^a	214.5 ± 48 ^b	557.67 ± 118 ^c	<0.0001	Extremely significant
<i>H.bimaculatus</i>	52.00 ± 28 ^a	51.5 ± 19 ^a	87.17 ± 48 ^a	0.16	Not significant
<i>T.zillii</i>	89.83 ± 39 ^a	59.50 ± 22 ^a	168.67 ± 62 ^b	0.002	Very significant

Mean values were obtained from monthly fish frequencies.

The same superscript in a row shows no significant difference between the sampling sites.

Monthly variation of fish species in Jakara Reservoir shows that July has highest frequency for *C.gariepinus* (40.22%), *C.anguillaris* (58.33%), *H.bimaculatus* (26.92%) and *T.zillii* (25.68%), while for *O.niloticus* May was highest (21.81%), this is presented in table 3.

Table 3: Variation in Monthly Catches of Fish Species in Jakara Reservoir, Kano, Nigeria.

Months	<i>C. gariepinus</i> %	<i>C. angularis</i> %	<i>O. niloticus</i> %	<i>H.bimaculatus</i> %	<i>T. zillii</i> %
February	18.33	16.67	11.45	17.57	8.07
March	12.02	0.00	15.61	7.87	10.85
April	4.53	0.00	18.81	10.49	16.14
May	2.91	0.00	21.81	10.93	18.08
June	21.89	25.00	16.21	26.22	21.17
July	40.22	58.33	16.10	26.92	25.68

Shannon Weiner's and Simpson's indices of diversity shows slightly higher species diversity, in site B, then site C, site A was least in diversity. This is illustrated in Table 4.

Table 4: Species diversity Indices of Jakara Reservoir, from different Sampling Stations.

Diversity index	Site A	Site B	Site C
Number of species (S)	5	5	5
Number of individuals (N)	3548	2153	5613
Simpson's index (D)	0.432	0.412	0.413
Simpson's index of diversity (D-1)	0.568	0.588	0.587
Shannon weiner's index (H')	1.092	1.129	1.126

Number of individuals (N) was obtained from monthly frequencies of their respective sites

On monthly bases, the trend of the Shannon-Weiner index and Simpson's index of diversity for the Reservoir can be depicted as July > June > February > March > April > May. The maximum value of fish species diversity was recorded in July whereas the minimum was observed in May. This is presented in table 5.

Table 5: Species diversity Indices of Jakara Reservoir, based on different Sampling Months.

Diversity Indices	February	March	April	May	June	July
No. species	5	4	4	4	5	5
No. of individuals	1399	1529	1775	1999	2127	2485
simpson's index	0.377	0.519	0.559	0.589	0.347	0.300
simpson's index of diversity	0.623	0.481	0.441	0.411	0.653	0.701
Shannon's weiner index	1.191	0.930	0.839	0.774	1.243	1.334

Number of individuals (N) was obtained from sampling site frequencies of their respective months

4.1.2 Population dynamics

4.1.2.1 *C.gariepinus*

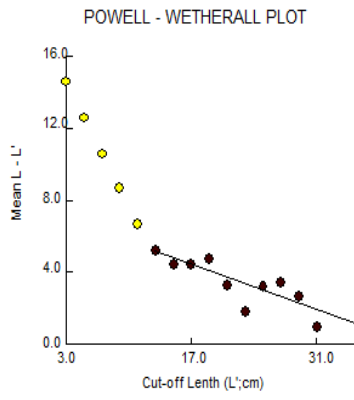
4.1.2.1.1 Growth Parameters

The results of growth parameters of *C.gariepinus* from Powell-Wetheral plot and K-scan of Shepherd's Length Composition Analysis (SLCA) method were presented in Table 6 and figure 2 and 3. *C.gariepinus* could reach a close asymptotic length (L_{∞}) of 36.25cm and 36.70cm, with an average growth curvature (K) of 0.11/yr in site A and C, and lower L_{∞} of 29.98cm with higher K of .090/yr in site B. These results gave growth performance indices (ϕ') of 2.16, 2.19 and 2.17 in site A, B and C respectively.

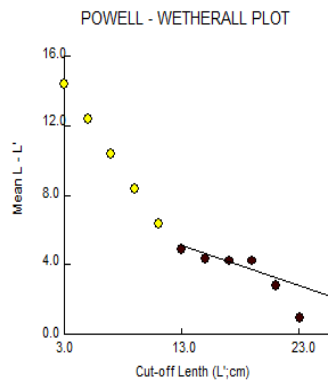
Table 6: Growth Parameters of *C.gariepinus* in Jakara Reservoir, Kano, Nigeria.

Methods	Sites	L_{∞} (cm)	Z/K	K ⁻ year	$\hat{\theta}$
Powell-	A	36.25	2.51	-	-
Wetheral	B	29.98	1.33	-	-
	C	36.70	2.63	-	-
Shepherd's	A	36.25	-	0.11	2.16
K-scan	B	29.98	-	0.90	2.91
routine	C	36.70	-	0.11	2.19

A



B



C

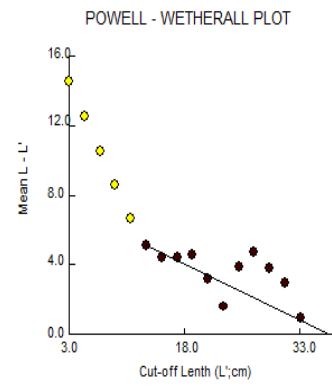
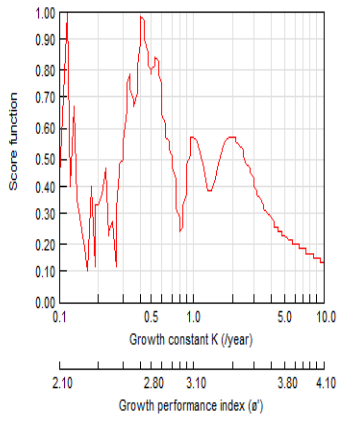
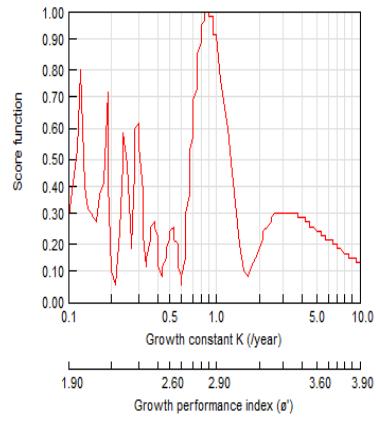


Figure 2: Powell-Wetherall Plot of *C. gariepinus* in Jakara Reservoir, Kano, Nigeria.

A



B



C

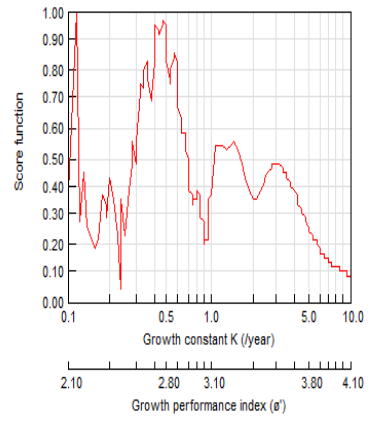
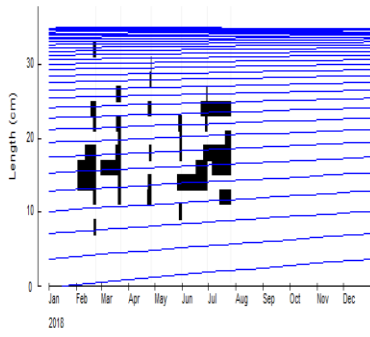


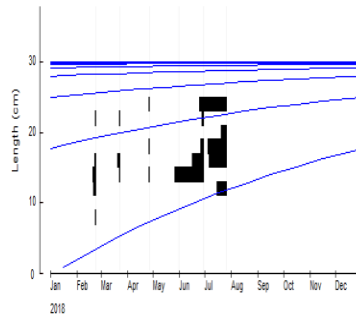
Figure 3: Shepherd Length Composition Analysis of *C. gariepinus* in Jakara Reservoir, Kano, Nigeria.

The seasonalized von Bertalanffy growth curve resulting from a combination of values obtained from Powell-Wetherall plot and SLCA method shows a fast growth rate in site B (Figure 4B) compared to site A and C (Figure 4A and 4C) which shows quite similar result due to their close asymptotic length and growth curvature.

A



B



C

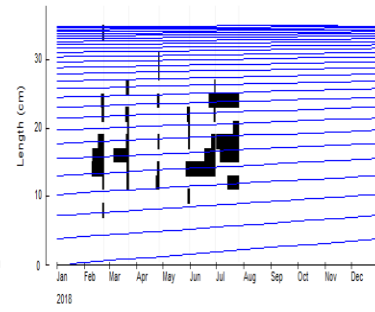


Figure 4: *C. gariepinus* Length Frequency and Fitted von Bertalanffy Growth Curves in Jakara Reservoir, Kano, Nigeria.

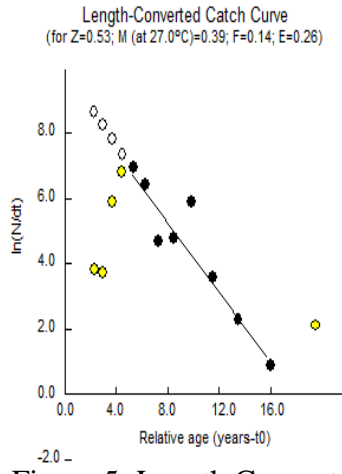
4.1.2.1.2 Mortality and Probability of capture

Coefficient of total mortality (Z) was estimated by using length converted catch curve, which found Z values of 0.53/yr in site A and 0.58/yr in site C relatively small compared to 4.45/yr value in site B. The values of natural mortality rate (M) obtained using empirical equation of Pauly (1980), by applying the estimated L_{∞} and K values obtained from SLCA and average water temperature of 27°C were 0.39/yr, 1.64/yr and 0.39/yr for the different sampling sites with site B having high natural mortality rate. The values of fishing mortality rate (F) were obtained by subtracting M from Z . It was found that site B has higher F value of 2.81/yr, followed by site C with 0.19/yr then site A with 0.14/yr. The values of the exploitation rate (E) were obtained by dividing F by Z . The estimated E was 0.26, for site A, 0.63 for site B and 0.32 for site C. Probability of capture shows that half of the catches were probably 13.98cm in site A, 16.54cm in site B and 13.96cm in site C. These were presented in Table 7 and Figure 5 and 6.

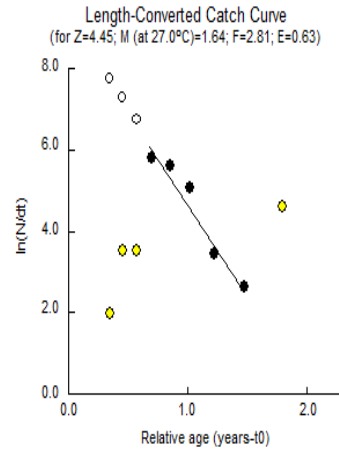
Table 7: Mortality and Probability of Capture of *C.gariepinus* in Jakara Reservoir, Kano, Nigeria.

Sites	Z year	M year	F year	E	L ₂₅	L ₅₀	L ₇₅
A	0.53	0.39	0.14	0.26	12.76	13.98	15.19
B	4.45	1.64	2.81	0.63	14.84	16.54	18.25
C	0.58	0.39	0.19	0.32	12.78	13.96	15.13

A



B



C

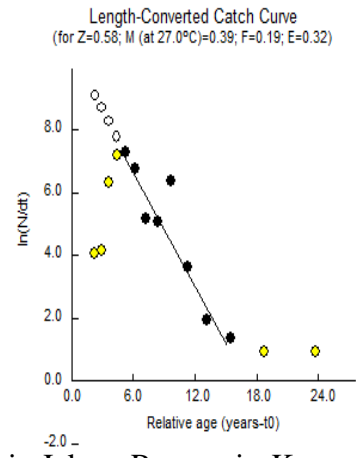
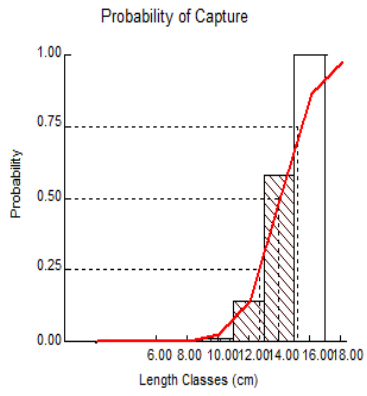
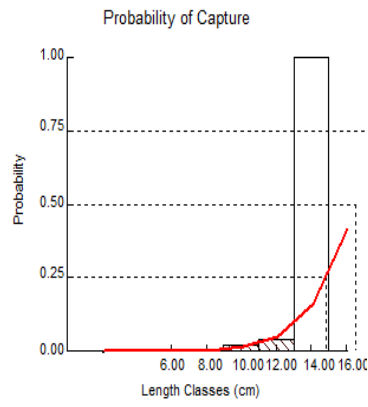


Figure 5: Length Converted Catch Curve of *C. gariepinus* in Jakara Reservoir, Kano, Nigeria.

A



B



C

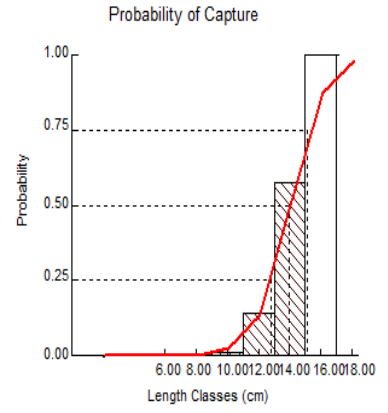
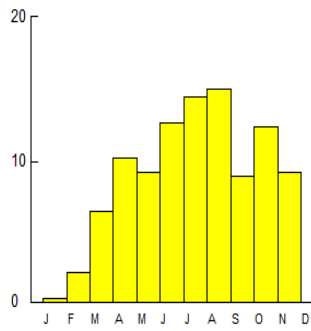


Figure 6: Probability of Capture of *C.gariepinus* in Jakara Reservoir, Kano, Nigeria.

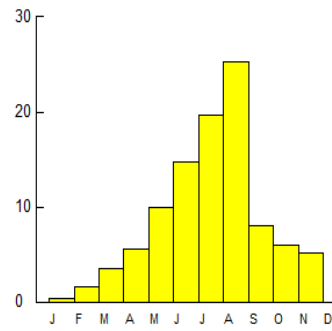
4.1.2.1.3 Recruitment

A continuous recruitment of *C.gariepinus* was done all along the year. It shows that there is major recruitment peak in August and minor one in July in all the sampling sites figure 7.

A



B



C

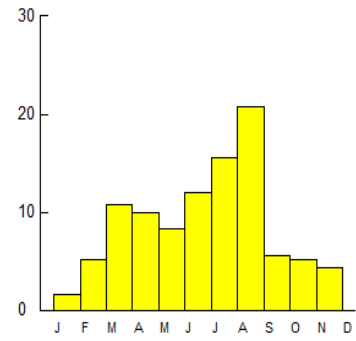


Figure 7: Recruitment Pattern of *C. gariepinus* in Jakara Reservoir, Kano, Nigeria.

4.1.2.1.4 Stock Assessment

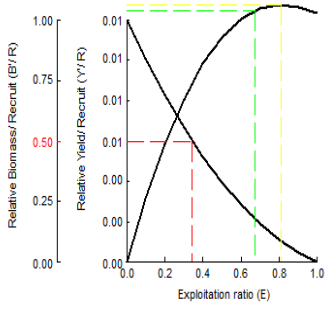
Relative yield per recruit and Relative biomass per recruit were analysed using knife-edge routine of Beverton and Holt Y/R analysis in FISAT (Table 8). The maximum exploitation rate was calculated as 0.81, 0.85 and 0.78, economic yield indices as 0.67, 0.71 and 0.66 and optimum exploitation rate as 0.34, 0.38 and 0.34 for site A, site B and site C respectively.

Table 8: Stock Assessment of *C.gariepinus* in Jakara Reservoir, Kano, Nigeria.

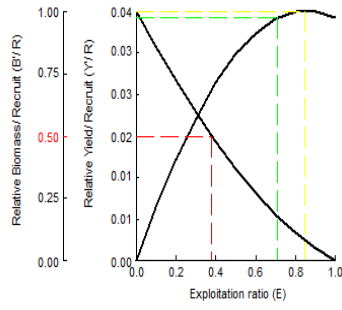
Sites	E_{\max}	$E_{0.1}$	$E_{0.5}$
A	0.81	0.67	0.34
B	0.85	0.71	0.38
C	0.78	0.66	0.34

From the analysis of mortality rates, the current exploitation rate was estimated as 0.26 in site A and 0.32 in site C which were below E_{\max} (0.81 and 0.78), $E_{0.5}$ (0.34 each) and $E_{0.1}$ (0.67 and 0.66) yield indices. 0.63 current exploitation rate in site B was slightly below E_{\max} and $E_{0.1}$ (0.85 and 0.71) but above $E_{0.5}$ (0.38) figure 8.

A



B



C

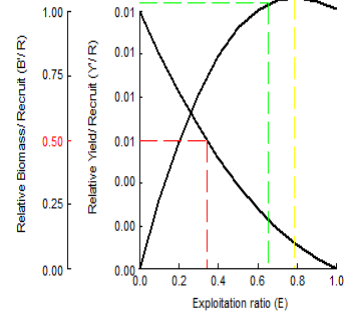


Figure 8: Relative Yield/Recruit and Relative Biomass/Recruit (Y'/R and B'/R) of *C.gariepinus* in Jakara Reservoir, Kano, Nigeria.

4.1.2.2 *O.niloticus*

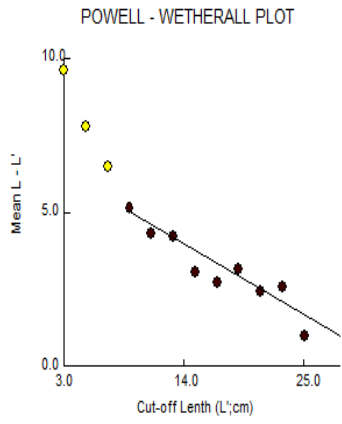
4.1.2.2.1 Growth Parameters

Growth parameters of *O.niloticus* from Jakara Reservoir were presented in table 9 and figure 9 and 10. Powell-Wetheral plot gave close L_{∞} values of 28.98cm, 29.51cm and 29.58cm, K-scan of SLCA gave K-value of 0.10/yr, 0.19/yr and 0.20/yr with the same L_{∞} values. Growth performance indices were 1.92, 2.22 and 2.24.

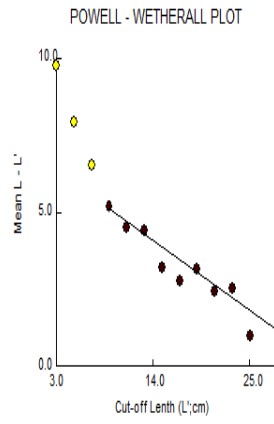
Table 9: Growth Parameters of *O.niloticuss* in Jakara Reservoir, Kano, Nigeria.

Methods	Sites	L_{∞} (cm)	Z/K	K ⁻ year	$\hat{\theta}$
Powell-	A	28.98	2.99	-	-
Wetheral	B	29.51	3.00	-	-
	C	29.58	3.02	-	-
Shepherd's	A	28.98	-	0.10	1.92
K-scan	B	29.51	-	0.19	2.22
routine	C	29.58	-	0.20	2.24

A



B



C

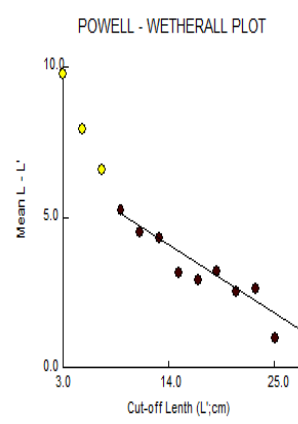
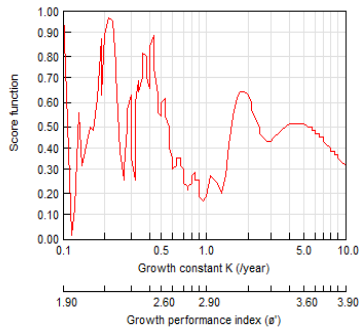
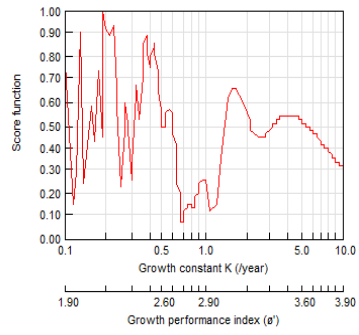


Figure 9: Powell-Wetherall Plot of *O.niloticus* in Jakara Reservoir, Kano, Nigeria.

A



B



C

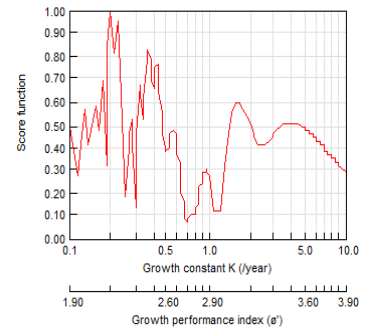
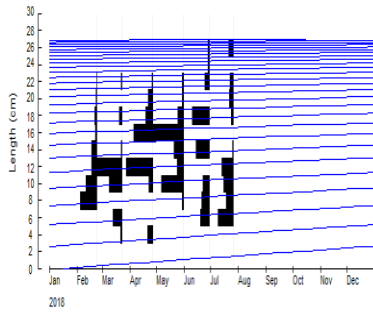


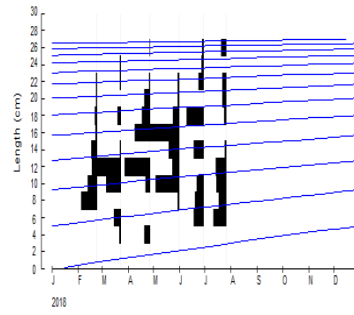
Figure 10: Shepherd Length Composition Analysis of *O.niloticus* in Jakara Reservoir, Kano, Nigeria.

Combination of asymptotic length and the period taking for *O.niloticus* to reach the asymptotic length were presented in figure 11, with slightly faster growth rate in site B and site C than in site A.

A



B



C

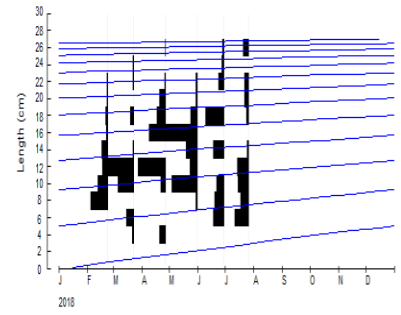


Figure 11: *O. niloticus* Length Frequency and Fitted von Bertalanffy Growth Curves in Jakara Reservoir, Kano, Nigeria.

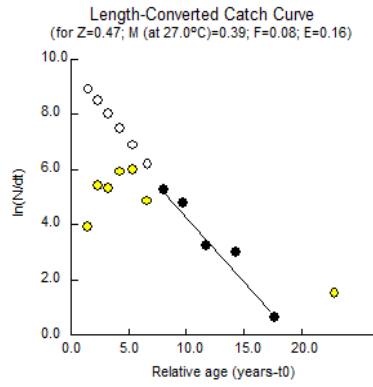
4.1.2.2.2 Mortality and Probability of Capture

The length converted catch curve analysis of *O.niloticus* in all the sampling sites produced lower total mortality (Z) estimates as 0.47/yr, 0.71/yr and 0.82/yr, natural mortality (M) calculated using Pauly's empirical formula (Pauly 1980), was still low 0.39/yr, 0.60/yr and 0.62/yr and relatively the same in both locations, fishing mortality (F) was estimated as 0.08/yr, 0.11/yr and 0.21/yr respectively. Exploitation rate E was 0.16, for site A and site B each and 0.25 for site C. Probability of capture shows that majority of the catches were 16.93cm in site A, 11.27cm in site B and 11.63cm in site C. These were presented in Table 10 and figure 12 and 13.

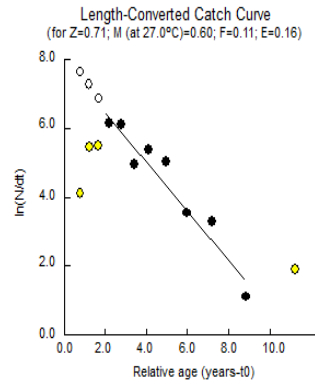
Table 10: Mortality and Probability of Capture of *O. niloticus* in Jakara Reservoir, Kano, Nigeria.

Sites	Z year	M year	F year	E	L ₂₅	L ₅₀	L ₇₅
A	0.47	0.39	0.08	0.16	11.66	14.30	16.93
B	0.71	0.60	0.11	0.16	7.62	9.45	11.27
C	0.82	0.62	0.21	0.25	8.09	9.86	11.63

A



B



C

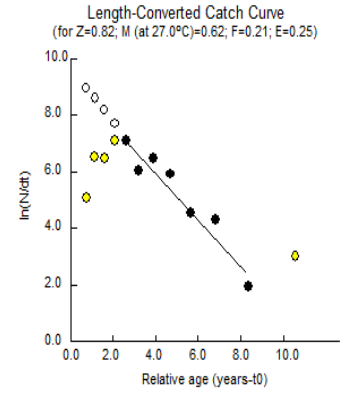
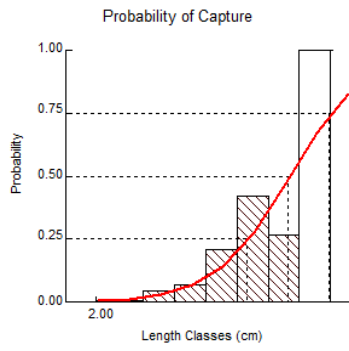
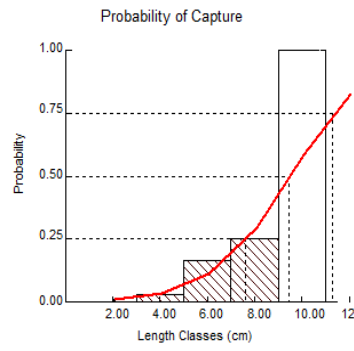


Figure 12: Length Converted Catch Curve of *O. niloticus* in Jakara Reservoir, Kano, Nigeria.

A



B



C

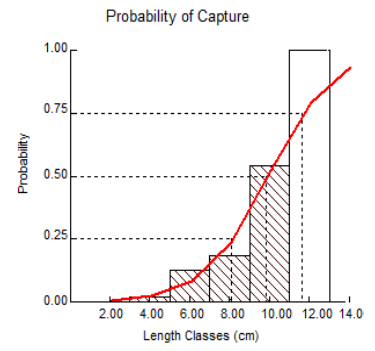
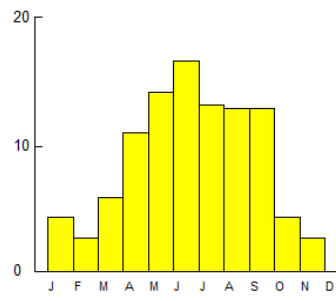


Figure 13: Probability of Capture of *O. niloticus* in Jakara Reservoir, Kano, Nigeria.

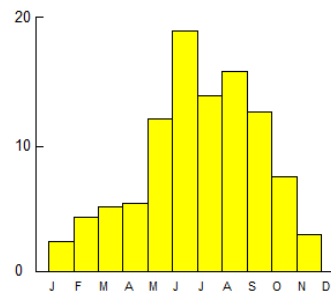
4.1.2.2.3 Recruitment

The recruitment pattern was continuous year-round with major peak in June for all the 3 sampling sites. The minor peak differs; for site A, it is in May and for site B and C it is in August, figure 14.

A



B



C

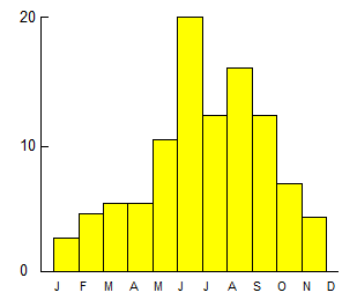


Figure 14: Recruitment Pattern of *O. niloticus* in Jakara Reservoir, Kano, Nigeria.

4.1.2.2.4 Stock Assessment

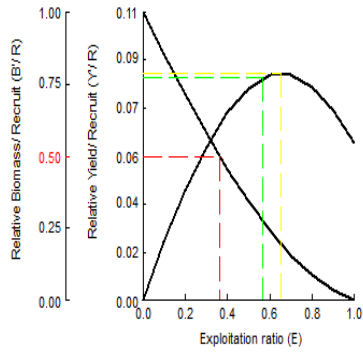
The Beverton and Holt relative yield per recruit model Table 11 showed that the indices for sustainable yields were 0.36, 0.31 and 0.32 for optimum sustainable yield ($E_{0.5}$), 0.66, 0.63 and 0.64 for the maximum sustainable yield (E_{max}) and 0.57, 0.52 and 0.52 for economic yield target ($E_{0.1}$) in site A, B and C respectively.

Table 11: Stock Assessment of *O.niloticus* in Jakara Reservoir, Kano, Nigeria.

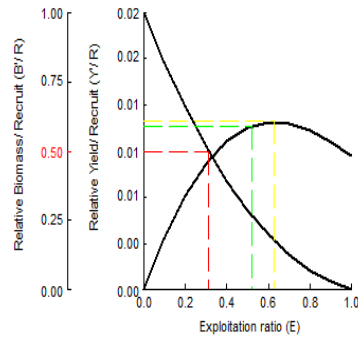
Sites	E_{\max}	$E_{0.1}$	$E_{0.5}$
A	0.66	0.57	0.36
B	0.63	0.52	0.31
C	0.64	0.52	0.32

From the analysis of mortality, the current exploitation rates were estimated as 0.16, 0.16 and 0.25 respectively which were below all the sustainable yields indices figure 15.

A



B



C

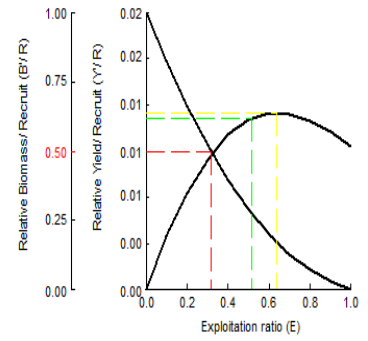


Figure 15: Relative Yield/Recruit and Relative Biomass/Recruit (Y'/R and B'/R) of *O.niloticus* in Jakara Reservoir, Kano, Nigeria.

4.1.2.3 *H.bimaculatus*

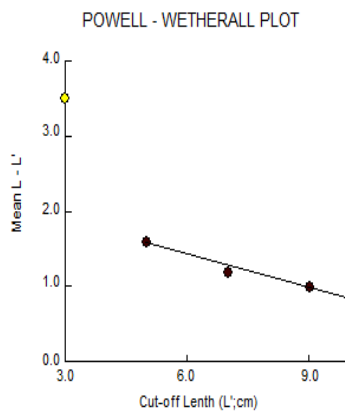
4.1.2.3.1 Growth Parameters

Powell-Wetherall plots for the estimation of L_{∞} and Z/K and SLCA for K-value estimation of *H.bimaculatus* were given in table 12 and figure 16 and 17. The L_{∞} values obtained were 13.75cm, 12.29cm and 12.26cm, K values were 0.20/yr, 0.27/yr and 0.28/yr and growth performance index were 1.58, 1.61 and 1.62 from the sampling stations respectively.

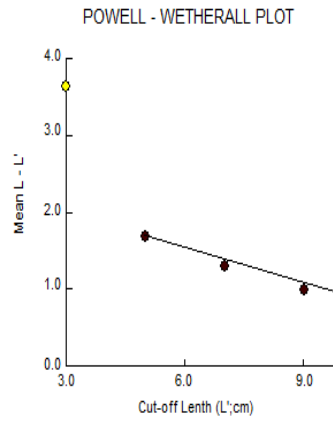
Table 12: Growth Parameters of *H.bimaculatus* in Jakara Reservoir, Kano Nigeria.

Methods	Sites	L_{∞} (cm)	Z/K	K _{year}	$\hat{\theta}$
Powell-	A	13.75	4.51	-	
Wetheral	B	12.29	4.37		
	C	12.26	3.77		
Shepherd's	A	13.75	-	0.20	1.58
K-scan	B	12.29	-	0.27	1.61
routine	C	12.26	-	0.28	1.62

A



B



C

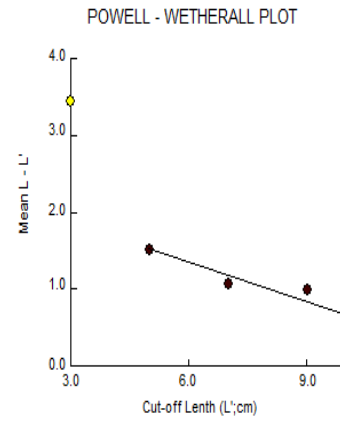
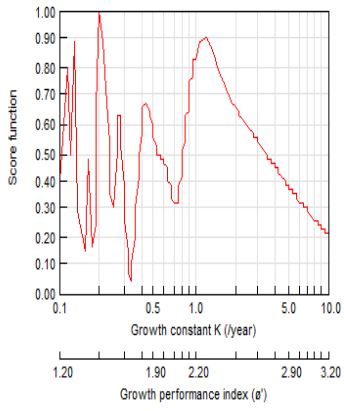
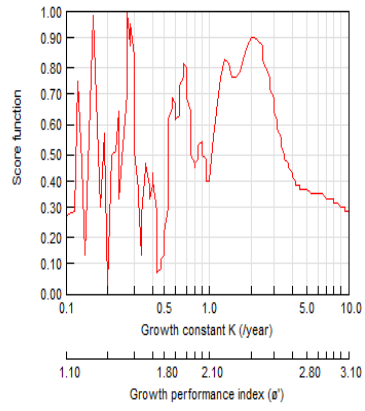


Figure 16: Powell-Wetherall Plot of *H. bimaculatus* in Jakara Reservoir, Kano, Nigeria.

A



B



C

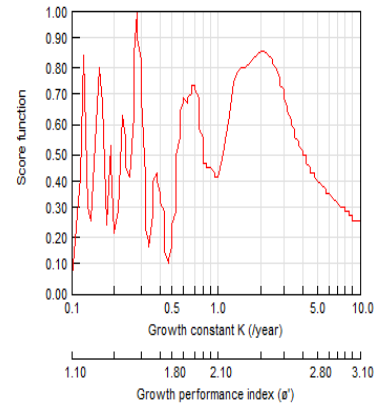
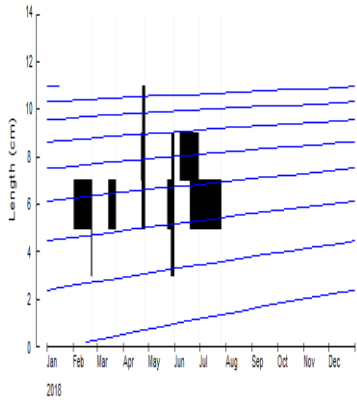


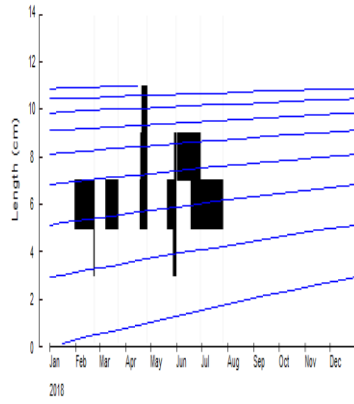
Figure 17: Shepherd Length Composition Analysis of *H. bimaculatus* in Jakara Reservoir, Kano, Nigeria.

Von Bertalanffy growth curves in figure 18 were similar in both asymptotic length and growth curvature.

A



B



C

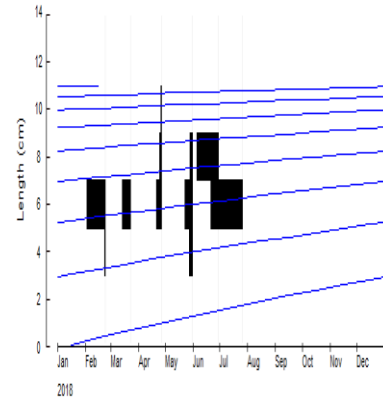


Figure 18: *H. bimaculatus* Length Frequency and Fitted von Bertalanffy Growth Curves in Jakara Reservoir, Kano, Nigeria.

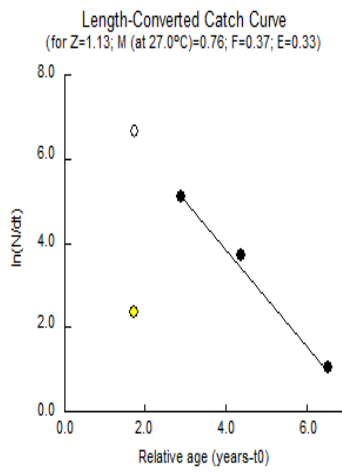
4.1.2.3.2 Mortality and Probability of Capture

The length-converted catch curve gave close total mortality rates of 1.13/yr, 1.01/yr and 1.51/yr, natural mortality 0.76/yr, 0.96/yr and 0.98/yr and fishing mortality 0.37/yr, 0.50/yr and 0.53/yr, exploitation rates were calculated as 0.33, 0.05 and 0.35. Probability of capture shows that majority of the catches were close to 6.5cm in all the sampling stations. These were illustrated in table 13 and figure 19 and 20.

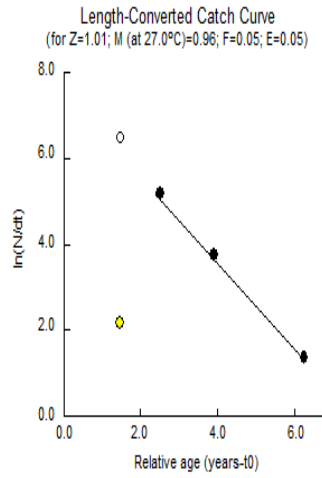
Table 13: Mortality and Probability of Capture of *H.bimaculatus* in Jakara Reservoir, Kano, Nigeria.

Sites	Z year	M year	F year	E	L ₂₅	L ₅₀	L ₇₅
A	1.13	0.76	0.37	0.33	3.47	4.97	6.48
B	1.01	0.96	0.05	0.05	3.47	4.97	6.48
C	1.51	0.98	0.53	0.35	3.48	4.98	6.49

A



B



C

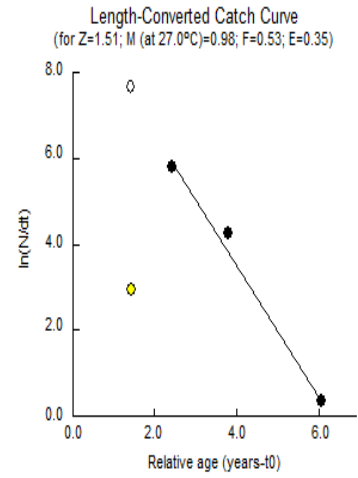
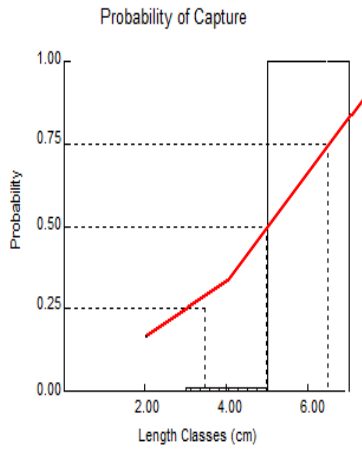
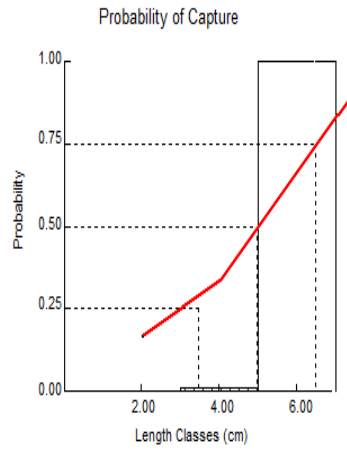


Figure 19: Length Converted Catch Curve of *H. bimaculatus* in Jakara Reservoir, Kano, Nigeria.

A



B



C

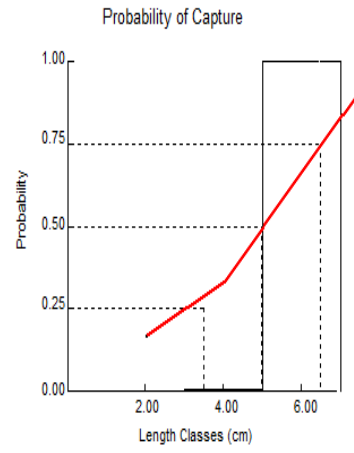
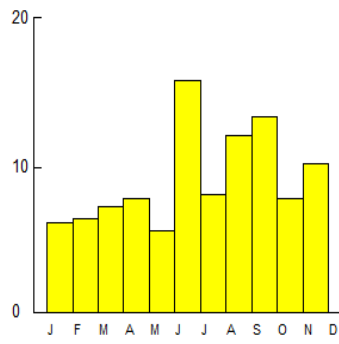


Figure 20: Probability of Capture of *H. bimaculatus* in Jakara Reservoir, Kano, Nigeria.

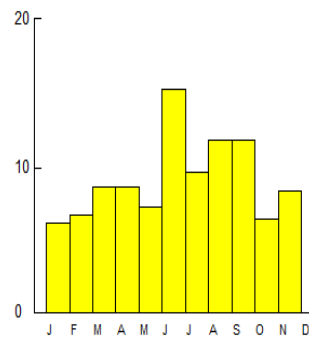
4.1.2.3.3 Recruitment Pattern

The recruitment pattern was continuous year-round with major peak in June for all the 3 sampling stations and minor one in September for site A, August and September for site B and site C.

A



B



C

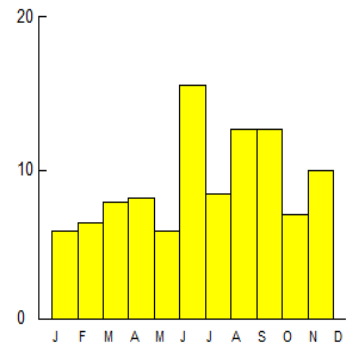


Figure 21: Recruitment Pattern of *H. bimaculatus* in Jakara Reservoir, Kano, Nigeria.

4.1.2.3.4 Stock Assessment

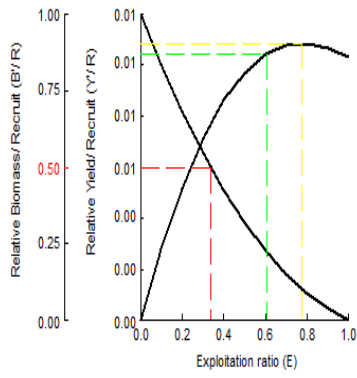
Relative yield per recruit and Relative biomass per recruit routine of Beverton and Holt Y/R model shows close values of optimum exploitation rate ($E_{0.5}$) A = 0.34, B = 0.35 and C = 0.35 and varies slightly in maximum (E_{Max}) A = 0.77, B = 0.84 and C = 0.85 and economic ($E_{0.1}$) A = 0.61, B = 0.65 and C = 0.71 yield indices from the 3 sampling stations table 14.

Table 14: Stock assessment of *H.bimaculatus* in Jakara Reservoir, Kano Nigeria.

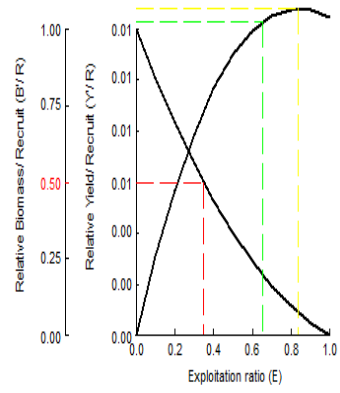
Sites	E_{\max}	$E_{0.1}$	$E_{0.5}$
A	0.77	0.61	0.34
B	0.84	0.65	0.35
C	0.85	0.71	0.35

From the analysis of mortality rates, the current exploitation rate in site A (0.33) was below the maximum (0.77), optimum (0.34) and economic (0.61) yield indices. 0.05 current exploitation rates in site B was also below the optimum, maximum and economic yield (0.35, 0.84 and 0.65 respectively). Current exploitation is the same with optimum exploitation (0.35) and below maximum (0.85) and economic (0.71) yield in site C.

A



B



C

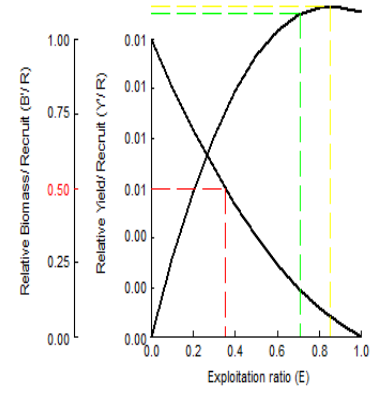


Figure 22: Relative Yield/Recruit and Relative Biomass/Recruit (Y'/R and B'/R) of *H.bimaculatus* in Jakara Reservoir, Kano, Nigeria.

4.1.2.4 *T.zillii*

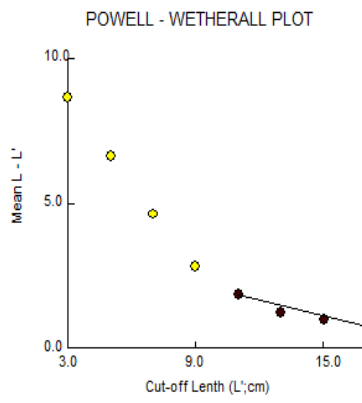
4.1.2.4.1 Growth Parameters

Growth parameters of *T.zillii* from Jakara Reservoir were presented in table 15 and figure 23 and 24. Powell-Wetheral plot gave L_{∞} values of 17.98cm, 16.16cm and 17.77cm, K-scan of SLCA gave K-values of 0.25/yr, 0.29/yr and 0.27/yr and growth performance index of 1.90, 1.88 and 1.93 from site A, B and C respectively.

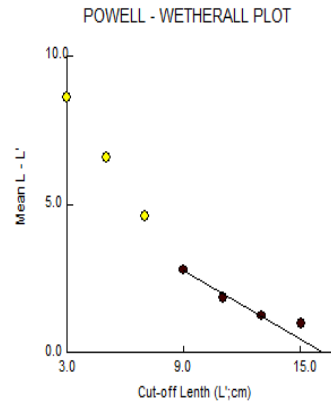
Table 15: Growth Parameters of *T.zillii* in Jakara Reservoir, Kano, Nigeria.

Methods	Sites	L_{∞} (cm)	Z/K	K ⁻ year	$\hat{\theta}$
Powell-	A	17.98	2.75	-	
Wetheral	B	16.16	1.59		
	C	17.77	2.60		
Shepherd's	A	17.98	-	0.25	1.90
K-scan	B	16.16	-	0.29	1.88
routine	C	17.77	-	0.27	1.93

A



B



C

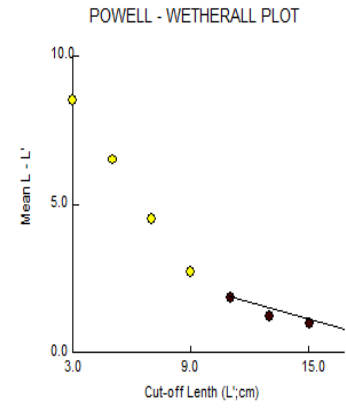
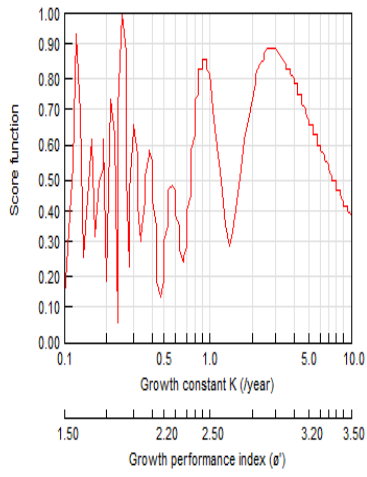
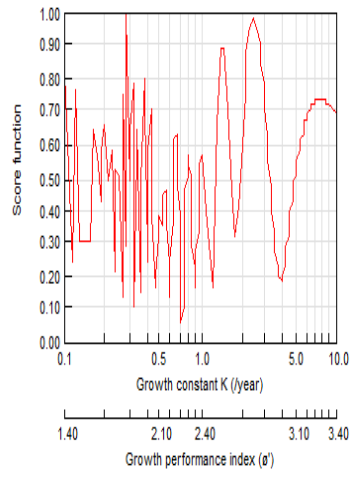


Figure 23: Powell-Wetherall Plot of *T.zillii* in Jakara Reservoir, Kano, Nigeria.

A



B



C

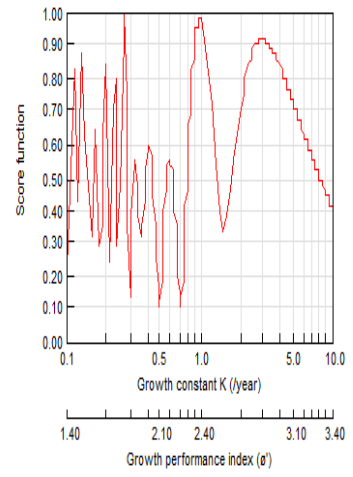
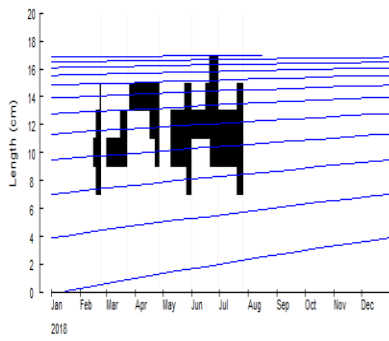


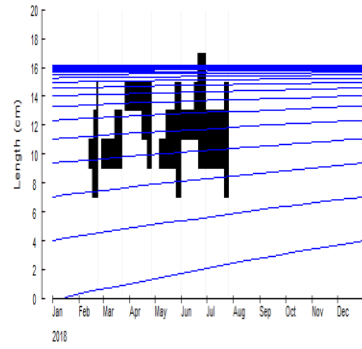
Figure 24: Shepherd Length Composition Analysis of *T.zillii* in Jakara Reservoir, Kano, Nigeria.

Asymptotic length (L_{∞}) and the rate it was achieved (K) for *T.zillii* in Jakara Reservoir was presented in figure 25.

A



B



C

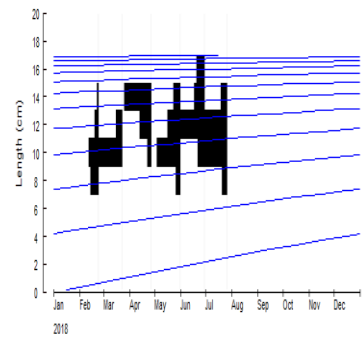


Figure 25: *T.zillii* Length Frequency and Fitted von Bertalanffy Growth Curves in Jakara Reservoir, Kano, Nigeria.

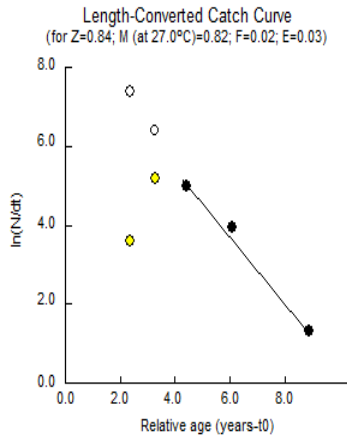
4.1.2.4.2 Mortality and Probability of Capture

Mortality rates and probability of capture of *T.zillii* was presented in table 16. Z was calculated from negative slope of length converted catch, M from pauly's empirical formula and F by subtracting M from Z. For site A, Z was calculated as 0.84, M = 0.82 and F = 0.02. For site B, Z = 0.48, M = 0.93 and F = 0.45. For site C, Z = 0.87, M = 0.86 and F = 0.01 for site C figure 26. Probability of capture shows that 25% of the captured fishes were probably 9.85cm in site A, 7.33cm in site B and 9.65cm in site C figure 27.

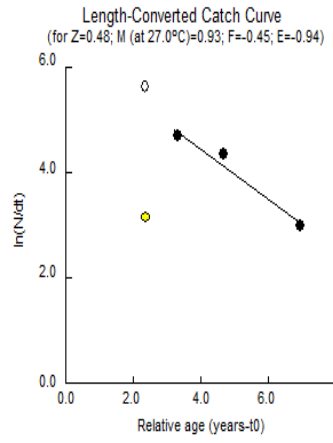
Table 16: Mortality and Probability of Capture of *T.zillii* in Jakara Reservoir, Kano, Nigeria.

Sites	Z year	M year	F year	E	L ₂₅	L ₅₀	L ₇₅
A	0.84	0.82	0.02	0.03	9.85	10.62	11.38
B	0.48	0.93	0.45	0.94	7.33	8.83	10.36
C	0.87	0.86	0.01	0.01	9.65	10.41	11.17

A



B



C

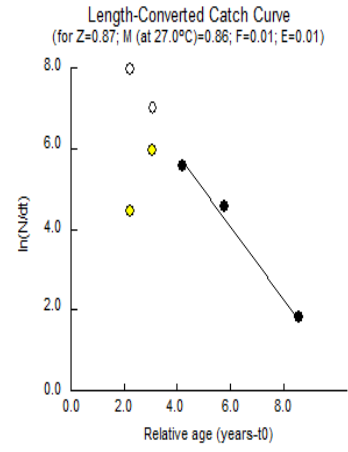
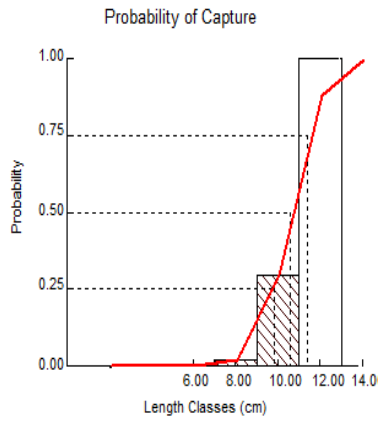
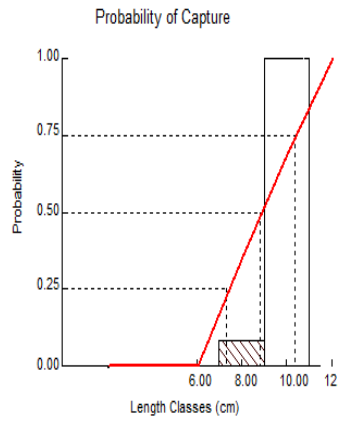


Figure 26: Length Converted Catch Curve of *T.zillii* in Jakara Reservoir, Kano, Nigeria.

A



B



C

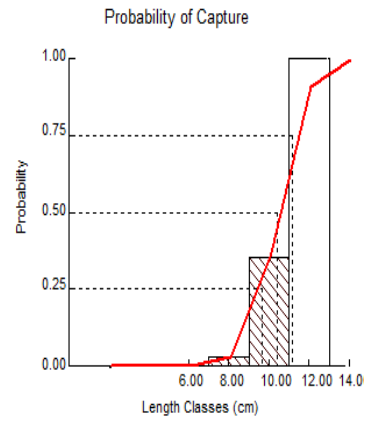
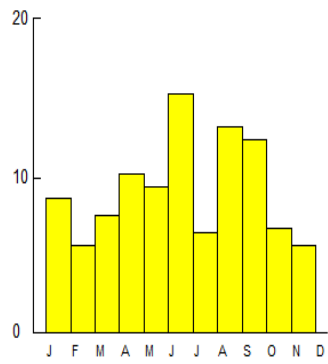


Figure 27: Probability of Capture of *T.zillii* in Jakara Reservoir, Kano, Nigeria.

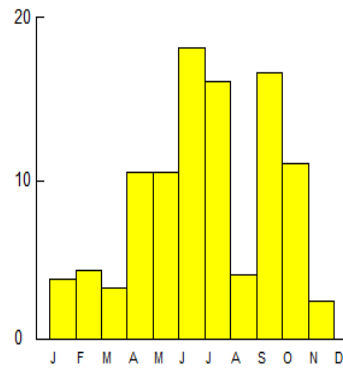
4.1.2.4.3 Recruitment Pattern

A continuous recruitment of *T.zillii* was done all along the year. It shows that there is major recruitment peak in June for all the sampling sites, minor recruitment is in August in site A and September in site B and site C.

A



B



C

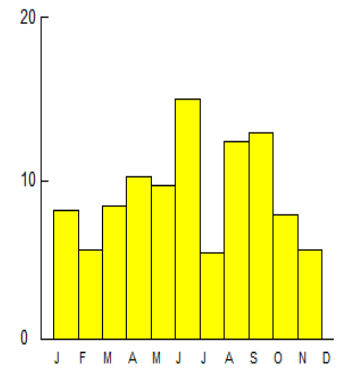


Figure 28: Recruitment Pattern of *T.zillii* in Jakara Reservoir, Kano, Nigeria.

4.1.2.4.4 Stock Assessment

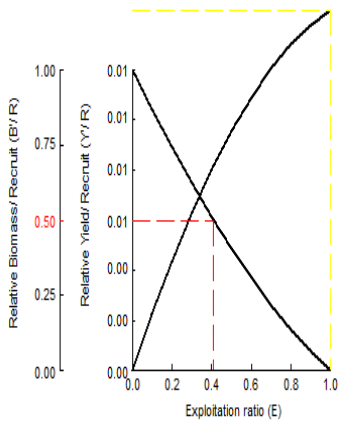
The Beverton and Holt relative yield per recruit model table 17 shows that the indices for sustainable yields were 0.41, 0.40 and 0.41 for optimum sustainable yield ($E_{0.5}$), 1.00 for maximum (E_{Max}) and economic yield indices ($E_{0.1}$) in all the sampling stations.

Table 17: Stock assessment of *T.zillii* in Jakara Reservoir, Kano Nigeria.

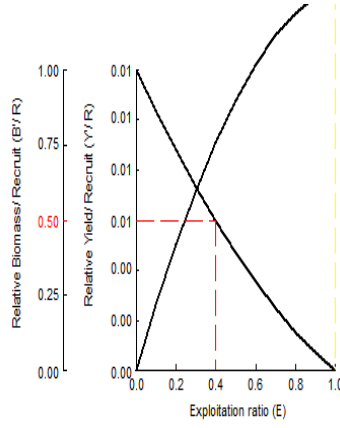
Sites	E_{\max}	$E_{0.1}$	$E_{0.5}$
A	1.00	1.00	0.41
B	1.00	1.00	0.40
C	1.00	1.00	0.41

From the analysis of mortality rates, the current exploitation rates were estimated as 0.03, 0.94 and 0.01 which were below all the sustainable yield indices in site A and C, and above optimum sustainable yield in site B figure 29.

A



B



C

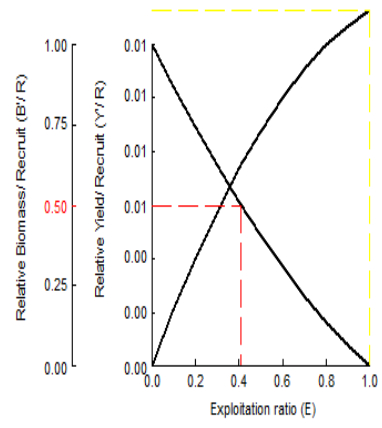


Figure 29: Relative Yield/Recruit and Relative Biomass/Recruit (Y'/R and B'/R) of *T.zillii* in Jakara Reservoir, Kano, Nigeria.

4.1.3 Length-Weight Relationship and Condition Factor

Length-weight relationship and condition factor of fish species in Jakara Reservoir was presented in table 18. Negative allometric growth was observed in all the species with b values of 1.53, 1.83, 1.14, 1.41 and 1.48 for *C.gariepinus*, *O.niloticus*, *H.bimaculatus*, *T.zillii* and *C.anguillaris* respectively. Only *H. bimaculatus* have higher condition factor which shows good physiological condition of this specie, while the remaining species were not doing well.

Table 18: Length-Weight Regression Analysis and Condition Factor of Fish Species in Jakara Reservoir, Kano, Nigeria.

Species	Intercept (a)	Slope (b)	Condition factor (K)	Correlation coefficient (r)	pattern	
<i>C.gariepinus</i>	-0.26	1.53	0.85	0.96	Negative growth	allometric
<i>O.niloticus</i>	-.038	1.83	2.44	0.96	Negative growth	allometric
<i>H.bimaculatus</i>	-0.06	1.14	3.06	0.97	Negative growth	allometric
<i>T.zillii</i>	-0.03	1.41	2.17	0.98	Negative growth	allometric
<i>C.anguillaris</i>	-0.18	1.48	0.69	0.96	Negative growth	allometric

4.2 Discussion

4.2.1 Biodiversity

The study revealed only two fish families in Jakara Reservoir, three species of Cichlids (*O. niloticus*, *T.zilliii* and *H.bimaculatus*) and two species of Clarids (*C.gariepinus* and *C.anguillaris*). Imam *et al.* (2010) reported similar results in Jakara Reservoir with the exception of *C.anguillaris*, this may be attributed to differences in sampling sites. A total of only five fish species in this research was an indication that this Reservoir was not rich in species and less diverse when compared with other findings in different water bodies. Boulenger (1916) published a list of African fresh water fishes to include 976 species, referable to 185 genera and 43 families. NARESCON (1992) showed that the fresh water fishery resources in Nigeria comprised of over 200 species from the inland waters, with Kainji having about 100 species while Lake Chad has 87 species. Eight (8) genera consisting of eleven (11) different species; *Clarias gariepinus*, *Oreochromis niloticus*, *Schilbedea micropogon*, *Tilapia zilli*, *Petrocephalus bovei*, *Protopterus annectens*, *Alestes nurse*, *Mormyrus rume*, *Tilapia guntheri*, *Sarotherodon galileaus* and *Lates niloticus* were recorded in Daberam Reservoir Katsina, Nigeria by Lawan and Ahmad (2014). The low diversity encountered in this research was linked to lower K value which indicates poor physiological condition of the species. This is probably due to waste water discharged from the city which pollutes the reservoir (Abubakar & Abdullahi, 2015; Dike *et al.*, 2013; Ibrahim & Said, 2010).

Family chichlidae dominate the reservoir with 87.32% percentage frequency. Lowe-McConnell (1975) and Ita *et al.* (1982) reported that family Cichlidae is particularly abundance in many African reservoirs. Holden and Reed (1972) reported over 200

species of Cichlids in West African water bodies. Similarly, Daddy *et al.* (1991), Bankole *et al.* (1994), Olopade (2010) and Dankishiya *et al.* (2013 reported Cichlidae to be the dominant family in Tatabu Lake in Niger State, Alau Lake in Borno State, Oyan Dam in Ogun State and Usuma Reservoir in Bwari, Abuja all in Nigeria. The number encountered in the present study was lower than the results of Ikenweuwe *et al.* (2007) who recorded six species of Cichlids in Oyan Dam. The number of species will vary depending upon differences in the sampling methods and sampling effort, as well as fish abundance.

O.niloticus has the highest frequency (60.34%), followed by *T.zillii* with 16.86% percentage frequency. This is quite similar to the work of Abdullahi and Mukhtar (2015) with *O.niloticus* having 61% percentage abundance and *T.zillii* 16.60% frequency in Thomas Dam Dambatta. *H.bimaculatus* was least in abundance among the Cichlidae family with only 10.11% of the population unlike in Daberam Dam where it dominates the reservoir with 85% percentage abundance in the work of Lawan and Ahmad (2014).

The dominance of family Cichlidae in the present study could be attributed to the high prolific breeding nature of the family members and this compares favorably in Bakolori (Reynolds, 1973), Tiga (Ita *et al.*, 1982), Geriyo (Dankishiya & Abdulrahman, 2007) and other African Reservoirs where cichlids are known to dominate them. Bala *et al.* (2009) also stated that high percentage frequency of cichlids is attributed to their fecundity and parental care to young ones. In terms of feed, cichlids consume virtually every type of food sources available in the freshwater habitat they are found.

Claridae with 12.68% percentage frequency was least abundant compared to Chichlidae (87.32%), this is similar in many other researches. Dankishiya *et al.* (2013) reported Claridae with least percentage of 3.93% in Usuma Reservoir, Abuja. *C.gariepinus* was reported present in Thomas and Daberam Dam by Abdullahi & Mukhtar (2015) with only 1% frequency in Danberam Dam, Katsina State and 4% in Thomas Dam, Kano State.

There are no significant differences with p-value >0.05 For *C.gariepinus*, *C.anguillaris* and *H.bimaculatus* in all the sampling sites, this is due to low frequency of these species in these sites. On the other hand, *O.niloticus* shows an extremely significant difference in both the sampling sites due to its highest frequency and *T.zillii* shows significant difference only in site C.

All the species were not evenly distributed but present throughout the research period except *C.anguillaris* which was present in only 3 months of the study period (February, June and July). Percentage frequency of *C.gariepinus* and *C.anguillaris* decreases from February to May and start increasing from June to July. On the other hand, *O.niloticus* increases from February to May and slightly decreases from June to July, the rationale behind this is probably due to competition with claridae who start rising in these periods. *H.bimaculatus* and *T.zillii* increases throughout the study period except in March for *H.bimaculatus*. This indicated that Claridae's abundance have more effect on *O.niloticus* than *H.bimaculatus* and *T.zillii* abundance.

The diversity indices reveal that Jakara Reservoir is not diverse in terms of fish species. The Simpson's index of diversity in this study was less than 1, indicating imperfect evenness. Shannon- Weiner index shows that site B was slightly higher in diversity than

site C while site A was the least due to low number of species in it (*C.anguillaris* only present in June and July). This is similar to findings of Olapade *et al.* (2014) where the Shannon-Weiner index indicates low species diversity of cichlids in Oyan Dam Ogun State, Nigeria.

On monthly bases, the trend of the Shannon-Weiner index and Simpson's index of diversity for Jakara Reservoir can be depicted as July > June > February > March > April > May.

4.2.2 Growth and Mortality

C.gariepinus

Asymptotic length and growth rate in site A and C were closely the same with L_{∞} value of 36.25cm and 36.70cm and K value of 0.11/yr each, these values deviate from site B with 29.98cm and 0.90/yr asymptotic length and growth constant respectively. The difference in asymptotic length is due to high fishing of this specie in site B hence not allowing it to reach larger sizes. The growth rate also varies with higher value in site B due to negative correlation that exist between L_{∞} and K values (Murugan *et al.*, 2014). These values were close to finding of Lawrence and Sa (2015) with L_{∞} value of 27.5cm and K value of 0.29/yr for catfish in Cross River, and were not the same with work of Apegyah *et al.* (2008) with higher asymptotic length of 61.98cm and growth rate of 0.09/yr, Okogwu (2011) with much higher L_{∞} value of 80.24cm this deviation may be due to differences in research reservoirs. Gulland and Rosenberg (1992) suggested that estimates can vary from one water body to another, since environmental factors such as lake productivity, food availability and predation may vary.

Total mortality was higher in site B than the other 2 sites due to its higher growth constant (Murugan, *et al.*, 2014). Death is brought about by natural factors in site A and C rather than fishing which is totally different in site B because this site is more accessible to people and majority prepared *C.gariepinus* than other species due to its taste and aroma making it highly prized (Okogwu, 2011). The main problem is smaller sized individuals were captured without allowing them to reach more profitable sizes. The coefficient of total, natural and fishing mortality in site A and C were lower than values obtained by Lawrence *et al.* (2015) with higher values in site B and almost similar exploitation rate meaning catfish were higher in Jakara Dam than in Cross River probably due to less competition in the former due to few species in it. Apegyah *et al.* (2008) found similar under exploited values of less than 0.5 for *C.gariepinus* in Bontaga reservoir Ghana as noticed in site A and C.

The current exploitation rate of 0.26 and 0.32 in site A and C were below optimum (0.34), maximum (0.81 and 0.78) and the economic (0.67 and 0.66) yield indices indicating that *C.gariepinus* were not overexploited as already explained by low number of fishing mortality, while in site B current exploitation of 0.63 is above optimum sustainable yield (0.38), and also above 0.5 as recommended by (Gulland, 1971) illustrating the presence of unsustainable exploitation due to intense fishing pressure on the targeted population, thus, supporting the earlier assertion that *C.gariepinus* is experiencing intense fishing pressure in site B.

O.niloticus

L_{∞} values for *O.niloticus* were 28.98cm, 29.51cm and 29.58cm for site A, B and C this shows almost the same results meaning that *O.niloticus* have the same length in the Dam in respective of sampling sites. The values of 0.20/yr, 0.19/yr and 0.10/yr growth constant also appeared to be almost the same, with slight variation due to slight variation in asymptotic length with lowest L_{∞} value having highest K value (Murugan, *et al.*,2014). These values were close to findings of Chekol (2006) in lake Ziway with L_{∞} value of 28.10cm and K value of 0.13/yr and lake Langano with L_{∞} value of 32.10cm and K value of 0.21/y, Novaes and Carvalho (2012) reported *O.niloticus* from Brazil with outcomes as $L_{\infty} = 33.60\text{cm}$ and $K = 0.36/\text{yr}$. Also this research agrees with findings of Bhanbhro *et al.* (2017) for *O.mossambicus* in Pakistan. These findings were higher than that of Marquez *et al.* (2008) with $L_{\infty} = 17.88\text{cm}$ and $K = 0.31/\text{year}$ in Mexico. Obtained values were lower in relation to those obtained by Feu (2004) who recorded L_{∞} value of 53.00cm and K value of 0.25/yr in Kainji Dam. The differences may be due to different analytical methods used and different community. Also Jakara Dam fish species has lower condition factor which indicates stress on the species.

Values for total mortality, natural mortality, fishing mortality and exploitation rate do not vary much from the 3 sampling sites. The higher natural mortality compared with fishing mortality is attributed to factors like diseases, old age, predation, spawning stress and starvation. Most of these causes are connected with the ecosystem where the fish lives (Murugan, *et al.*,2014). Higher natural mortality and lower exploitation rate was obtained by Bhanbhro, *et al.* (2017) for *O.mossambicus* in Pakistan. Apegyah *et al.* (2008) also found similar under exploited values of less than 0.5 for *O.niloticus* in Bontaga reservoir

Ghana with higher natural mortality rate. Getabu (1992) found low total mortality coefficient of 0.81/yr in Kenyan part of Lake Victoria. The present study differs from values obtained by Chekol (2006) in Koka, Ziway and Langano, Ethiopia.

The current exploitation rate of 0.16 in site A and B each and 0.25 in site C derived from the analysis of mortality rates, were below the maximum, optimum and economic yield indices. These values were also below 0.5 (Gulland, 1971) recommended exploitation ratio, meaning that the fishery of *O.niloticus* in Jakara Reservoir was not overexploited. The only problem is the fishermen cached small individuals instated of allowing them to reach market and profitable sizes; this statement was proven right due to high natural mortality than fishing mortality. Wehye & Amponsah (2017) stated that low fishing and high natural mortality in their study is related to the fact that accessed catch consists of more juvenile fishes than adults.

H.bimaculatus

In the present study, L_{∞} value for *H.bimaculatus* in site A, B and C were 13.75cm, 12.29cm and 12.26cm this implies that site B and C have close values and differ slightly from site A. On the other hand, K value in all the sites were almost similar (0.20/yr, 0.27/yr and 0.28/yr) meaning they have close growth rate with slightly lower value in site A due to slightly higher asymptotic length in the site (Murugan, *et al.*, 2014). All these values were larger than findings of Indira and Pugazhendy, (2016) who reported L_{∞} = 6.6cm, K = 0.52/yr for males and L_{∞} = 5.9cm, K = 0.75/yr for females in India. The rationale behind this is that there is a tremendous scope for farming and trade of ornamental fish like *H.bimaculatus* in India (Mahapatra, 1999), hence lowering their growth.

Mortality was more of natural process than fishing activities due to lower condition factor. The coefficient of both total, natural and fishing mortality were almost equal in all the sampling stations with lower exploitation in site B probably due to preference of *C.gariepinus* in the area. These findings were similar to that of Apegyah *et al.* (2008) in Ghana.

The present exploitation rate of 0.33, 0.05 and 0.35 in site A, B and C were less than maximum, optimum and economic yield indices. These values were also below 0.5 Gulland exploitation ratios hence *H. bimaculatus* is not over exploited in Jakara Reservoir.

T.zillii

T.zillii shows almost similar L_{∞} values of 17.98cm and 17.77cm in site A and C and differs in site B with 16.16cm asymptotic length and a little bit higher growth rate of 0.29/yr. This is due to negative correlation that exist between asymptotic length and growth rate (Murugan, *et al.*, 2014). Values of L_{∞} were much smaller than 38.33cm obtained by Abdul *et al.*, (2012) in Tropical coastal estuary and L_{∞} of 21.53cm obtained by Apegyah *et al.* (2008) for *T.zillii* in Ghana but agreed with Mahomoud *et al.* (2011) findings of $L_{\infty} = 17.85\text{cm}$ for female and 22.05cm for male in lake Timsah, Egypt. Gulland & Rosenberg (1992) suggested that estimates can vary from one water body to another, since environmental factors also varies.

As previously stated mortality in Jakara Reservoir is maximally caused by natural factors rather than fishing, this statement was also the same for *T.zillii* with small coefficient of fishing mortality in all the sampling stations. Efitre (2016) recorded low mortality for *T.zillii* in Lake Nkuruba, Uganda. High rate of natural mortality in site B compared to

total mortality is as a result of smaller animals having higher mortality rate (Ahmad *et al.*, 2018), as indicated by probability of capture were 75% of the catches were less than 11cm. These values disagreed with results of Mahomoud *et al.* (2011) with L_{75} greater than 12cm in Egypt. Exploitation was low in site A and C. Apegyah *et al.* (2008) also found similar under exploited values of less than 0.5 for *T.zillii* in Bontaga reservoir Ghana while Mahomoud *et al.* (2011) found higher exploitation rate in Egypt as in the case of site B.

The Beverton & Holt relative yield per recruit model showed that the indices for sustainable yields were 0.41, 0.40 and 0.41 for optimum sustainable yield, 1.00 for maximum and economic yield in all the sampling stations. From the analysis of mortality rates, the current exploitation rate were estimated as 0.03, 0.94 and 0.01 which were below all the sustainable yield indices in site A and C, and above optimum sustainable yield in site B, these values revealed that *T.zillii* is underexploited especially in site A and C as also indicated by low fishing mortality coefficient.

4.2.3 Recruitment

Recruitment occurred in almost all months of the year. However, the recruitment was more intense at certain periods than at others. It emerged that major recruitment occurred during the period of highest fish frequency which falls in June - August for all the species and in all the 3 sampling sites. The period for the lowest recruitment of young to the fishery tallied with the time the fishes were least in abundance in the artisanal catches (Amiye, 2004) therefore period of highest recruitment will be when fish catches is highest which is July- August. Besides the peak period of recruitment, recruitment occurred in other months too. Montcho *et al.*, (2015) recorded that peak recruitment of

O.niloticus was in May – July in lake Toho Benin. Njiru *et al.*, (2007) reported *O.niloticus* with continuous recruitment throughout the year, with two peaks corresponding with the rainy seasons, the major one in May to July and minor one in November and December. Uneke and Nwani (2014) reported *T. zillii* with continuous recruitment pattern in a Nigerian tropical river basin with major recruitment in May to June. The recruitment pattern of *C.gariepinus* shows double annual peak recruitment per year, the first peak in June and the second one in August in the work of Okogwu, (2011).

4.2.4 Length-Weight Relationship and Condition Factor

Length weight relationship gives information on the condition and growth pattern of fish (Olurin & Adenibigbe, 2006). It is also of great importance in fishery assessment (Gracia *et al.*, 1998; Haimovici & Valesco, 2000).

All the species exhibited negative allometric growth with b values obtained not up to 3. Meaning the weight gain in relation to length is not as high as the cube of the length (L^3). This value agreed with result of Imam *et al.* (2010) on Length-weight relationship and condition factor of four fish species from Wasai/Jakara Reservoir in Kano, Nigeria. Were all the b values does not reach 3. The result is also similar to findings of; Musa *et al.* (2016) were he found negative allometric growth for *O.niloticus* in Thomas Dam Kano, Nigeria, Lawrence and Sa (2015) who found negative allometric growth in *C.gariepinus* in Maiduguri Barno, Nigeria, Oyewo (2015) who reported allometric growth pattern for *C.gariepinus* and *O.niloticus* from Dogon Ruwa water body, Birnin Gwari, Kaduna, Nigeria, Dan kishiya (2013) who obtained negative allometric growth for *Tilapia zillii*, *Tilapia mariae*, *Oreochromis niloticus*, *Barbus occidentalis* and *Barilius loati* from Lower Usuma Reservoir in Abuja. While catfishes and tilapia show positive

allometric growth from Kainji Dam Nigeria in the work of (Feu, 2004). Olopade a Rufai and (2014) recorded *Sarotherodon galilaeus*, *Oreochromis niloticus*, *Tilapia zillii* and *Tilapia mariae* exhibited a positive allometric growth pattern while only *Hemichromis fasciatus* showed a negative allometric growth in Oyan Dam, Ogun state. Ahmad *et al.* (2015) found isometric growth in *T.zillii* in Kanye Dam Kano, Nigeria. Olurin and Aderibigbe (2006) reported that the difference in length weight relationship is as a result of sex, maturity, season and environmental conditions. However, Abubakar (2006) also observed that certain factors such as increase in weight due to intake of water or food, season of the year, and the time of the day when the fish was captured, could cause an increase in weight, similarly food regurgitation and spawning can among other things cause weight lost thus affecting “b” values. All the K values obtained were less than Bagenal and Tesch (1978) ideal ranges of 2.9 – 4.8 for normal physiological activities in fresh water fish except for *H.bimaculatus* which is in good physiological state.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

A survey of fish species diversity and population dynamics in Jakara Reservoir, Kano, Nigeria was conducted between February 2018 and July 2018. A total catch of approximately 11,314 fish samples was recorded from different fishermen. Length, weight and other morphometric measurements were carried out for identification, population dynamics analysis and length weight relationships. Only five species, belonging to two families were caught using seine net, gill net, cast net, clap net and some local traps (mali). The family Cichlidae dominated the catches by both number and abundance (9879 fish, 87.32%); *O.niloticus* was the numerically dominant species (6827 fish, 60.34%). Monthly abundance of all the fish species was highest in July (2485 fish, 21.96%); the dominant fish family in July was the Cichlidae (1897 fish, 76.34%), whereas, the other family; Claridae was fewer (588 fish, 23.66%). The fewest fish (1399 fish, 12.37%) were caught in February, with the dominant family being the Cichlidae (1137 fish, 81.27%) and the other family; Claridae was least prevalent, (262 fish, 18.73%). The largest fish was caught in February and was *Clarias gariepinus* with total length of 34.00 cm and a total weight of 153.85g; the smallest were caught in February, March and May, they were *H.bimaculatus* and *O.niloticus* with a total length of 4.00 cm each. *O.niloticus* had the lowest weight of 2.6g in March. The growth pattern of the fish species was negatively allometric with b values of 1.14 - 1.83.

In terms of population dynamics, FAO and ICLARM Stock Assessment Tools (FISAT) was used to figure out the growth, recruitment and mortality parameters which were

collectively termed rate function. *C.anguillaris* was not analysed due to low data which does not behave in the software. For the other four species, the estimate of K was around 0.9/yr, whilst L_{∞} was approximately 37 cm. for *C.gariepinus*, site A and C had the lowest value of K (0.11/yr each) and the largest L_{∞} (36.25cm and 36.70cm respectively). Mortality and exploitation were higher in site B due to accessibility of the site to people. For *O. niloticus* all the sites have similar asymptotic length and growth curvature of $L_{\infty} = 28.98\text{cm} - 29.58\text{cm}$ and $K = 0.10/\text{yr} - 0.20/\text{yr}$. Site C had slightly higher mortality (0.71) than site B (0.82) with site A having least (0.47) so also fishing and exploitation rate. For *H.bimaculatus*, L_{∞} was as small as 13.75cm in site A, 12.29cm in site B and 12.26cm in site C, K differ slightly (0.20/yr – 0.28/yr). Mortality was similar (1.10/yr – 1.51/yr) with site C having a little bit higher value. For *T.zillii* site A and C have similar L_{∞} (17.98cm and 17.77cm) and K (0.25/yr and 0.27/yr) and slightly deviate from site B ($L_{\infty} = 16.16\text{cm}$, $K = 0.29/\text{yr}$). Mortality follows the same trend. By using Gulland's exploitation rate of 0.5 and values obtained from relative yield and relative biomass per recruit (E_{Max} , $E_{0.1}$ and $E_{0.5}$), Jakara Reservoir fishes were not over exploited and economic target was not achieved especially in site A and C. Probability of capture shows that majority of the catches were fingerlings and juveniles and in some cases preys, hence less profitable.

5.2 Conclusion

In conclusion, Jakara Reservoir is less diverse, only two families were recorded; *C.anguillaris*, and *C.gariepinus*, belonging to family Claridae and *O.niloticus*, *H.bimaculatus* and *T.zillii* belonging to family Chichlidae. The available species were not evenly distributed in which Chichlids dominate the Reservoir with *O.niloticus* leading in the family. The catches were small in size and have slow growth rate. The Result of this study also revealed that there is selective mortality toward smaller sized fishes. This implies that fingerlings and juveniles individuals are the target of the fishery. Recruitment occurred in almost all months of the year. However, the recruitment was more intense at certain periods than at others. It emerged that major recruitment occurred during the period of highest fish frequency which falls from June to August for all the species. For the stock assessment, Jakara Reservoir fishes were not over exploited and economic target was not achieved due to growth overfishing (overexploitation of smaller species).

5.3 Recommendation

Jakara Reservoir should be stocked with more fish species for better fish diversity.

Larger mesh size for fishing should be used to reduce overexploitation.

REFERENCES

- Abdul, W.O., Omoniyi, I.T., Akegbejo-samsons, Y., Akinyemi, A.A., & Agbon, A.O. (2012). Management indicators and growth performance index of *Tilapia zillii* in a Tropical Coastal Estuary. *Journal of Agricultural Science*, 4(11), 66–71, <https://doi.org/10.5539/jas.v4n>
- Abdullahi, U.A. & Mukhtar, U.Y. (2015). Appraisal of the current fish composition , abundance and operative fishing gears in Tomas Dam Danbatta , Kano State and Daberam Dam Daura , Katsina State. *Bayero Journal of Pure and Applied Sciences*, 8(1), 6–9, <http://dx.doi.org/10.4314/bajopas.v8i1.2>
- Abeer, M.H., Mohamed K. , Abdel Raheem, H.A.E., Izelden, I.A., Eisa, M.A., & Adam, M.I. (2017). Length-weight relationship and condition factor of three commercial fish species of River Nile, Sudan. *EC oceanography Research Article 1*, 1–7.
- Abiodun, J.A., & John, P. (2017). Biodiversity and abundance of fish and some processing methods in lower Niger river Idah, Kogi State, Nigeria. *Nigerian Journal of Fisheries and Aquaculture*, 5(2), 20-25.
- Abubakar, A. & Abdullahi, B.A. (2015): Flora composition of phytoplankton as bioindicators of water quality in Jakara Dam, Kano state, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 8(2), 145-155. <http://dx.doi.org/10.4314/bajopas.v8i2.25>
- Abubakar, K.A. (2006). A study of aspects of productivity and stock status of *Oreochromis niloticus* and *Clarias gariepinus* in Lake Geriyo, Yola Adamawa State. PhD Thesis: Unpublished, 17-20.
- Adedeji, O.B., & Okocha, R.C. (2011). Constraint to aquaculture development in Nigeria and way forward, *Journal of Applied Sciences Research*, 7(7), 1133–1140.
- Adewumi, A.A., & Olaleye, V.F. (2011). Catfish culture in Nigeria : Progress , prospects and problems, *African Journal of Agricultural Research*, 6(6), 1281–1285, <https://doi.org/10.5897/AJAR09.361>
- Afami, A. & Okorie, P.U (2008). Some aspect of the reproductive biology of *Tilapia mariae* in a small Lake in South Eastern Nigeria. *African Journal of Biotechnology*, (14) 2478-2482.
- Agbugui, M.O. (2013). Length-weight relationship and condition factor of *Pomadasys Jubelini* in the new Calabar-Bonny River, Nigeria , *World Rural Observations* 2013, 5(4), 50-53, <http://www.sciencepub.net/rural>
- Ahmad, I.M., Yola, I.D. & Sulaiman. N. (2018). Mortality and exploitation rates of Challawa Gorge Dam fishes , Kano. *Journal of Fisheries & Livestock Production* 6(1), 1–10, <https://doi.org/10.4172/2332-2608.1000262>
- Ahmad, M.K., Baba, H.A., Haruna, M.A., Bichi, A.H., Abubakar, S., & Danba, E.P. (2015). Some aspects of the biology of *Tilapia zilli* in Kanye Dam , Kabo Local Government ,

- Kano State , Nigeria. *International Journal of Agriculture, Forestry and Fisheries*, 3(2), 32-36, <http://www.openscienceonline.com/journal/ijaff>
- Akinyemi, O., Ita, E.O. & Sado, E.K. (1985). A preliminary assessment of the post-impoundment fisheries of Lake Asejire, Oyo State, Nigeria. *Kainji Lake Research Institute Annual report*, 6: 44-50.
- Allen, M.S., & Pine W.E. (2000). Detecting fish population responses to a minimum length limit: effects of variable recruitment and duration of evaluation. *North American Journal of Fisheries Management*, 20, 672–682.
- Amiye, F., & Franci, D. (2004). Recruitment pattern and fish production within the Andoni River system in the Niger delta of Nigeria. *Journal of Animal and Environmental Biology*, 809 – 815.
- Apegyah, K.K., Nunee, F.K & Oferi-Danson, P.K. (2008). Exploitation rates and management implications for the fisheries of Bontanga Reservoir in the northern region of Ghana. *West African Journal of Applied Ecology*, 14, <https://doi.org/10.4314/wajae.v14i1.44710>
- Arome, G., & Ugondo, M. (2014). Fish species diversity and abundance of Gubi Dam , Bauchi State of Nigeria. *Asian Journal of Conservation Biology*, 3(1), 60–67.
- Atindana, S.A., Bulley, R., Alhassan, E.H., Abarike, E.D., A-Yeboah, A., Akongyuure, D.N., & Abobi, S.M. (2014). Stomach content analyses of *Tilapia zilli* and *Hemichromis fasciatus* in the Golinga Reservoir in the Tolon District of the northern region of Ghana. Proceedings of the 32nd Biennial Conference of the Ghana Animal Science Association, (2002), 23–28.
- Awachie, J.B.E. (1976). Fish culture possibilities on flood-plains of Niger-Benue drainage system. Central Institute of Freshwater Aquaculture Technical paper, 5, 170-184.
- Ayanda, I.O. (2009). Comparative parasitic helminth infection between cultured and wild species of *Clarias gariepinus* in Ilorin, North – Central, Nigeria. *Sci. Research and Essay*, 4(1), 18 – 21.
- Azeroual, A., Bousso, T., Getahun, A., Laleye, P.& Moelants, T. (2010). *Clarias anguillaris*: The Red List of Threatened Species 2010: e.T182189A7827640. <http://dx.doi.org/10.2305/IUCN.UK.2010-3.RLTS.T182189A7827640.en>. Retrieved on 03 April 2018.
- Badamasi, I. (2014). Distribution of stomach food content of fish species collected from industrial waste water effluents: A case study of Jakara Dam , Kano , Nigeria. *International Journal of Innovation, Management and Technology*, 5(2), <https://doi.org/10.7763/IJIMT.2014.V5.499>
- Bagenal, T.B. and Tesch, F.W. (1978): *Methods for assessment of fish production in freshwaters*. Oxford, Blackwell Scientific Publication. 350pp.
- Bailey, R.G. (1994). Guide to the fishes of the River Nile in the Republic of the Sudan. *Journal of Natural History*, 28,937-970.

- Balogun, J.K. (2005). Fish distribution in a small domestic water supply reservoir: a case study of Kangimi Reservoir, Kaduna, Nigeria. *Journal of Applied Science of Environmental Management*, 9(1), 93-97.
- Balogun, J.K. (2006). *Basic fisheries biology and management for tertiary institutions*. Zaria, Nigeria: Ayo-Sule (NIG) Printers & Publishers, 3-33.
- Balogun, J.K. & Auta, J. (2001). Fisheries resources and development potentials of Lake Kangimi, Kaduna State. *Nigerian Journal of Biological Sciences*.1(1), 50-56.
- Bankole, E.O., Sule, O.D., Okwundu, E.C., Amadi, M., Adeyemo, T., Olabanji, M. & Balogun, I. (1994). Preliminary investigation on the frame and catch assessment surveys of Alau Lake, Maiduguri, Borno State, Nigeria NIFFR Annual Report 1994, NIFFR, Nigeria .
- Banks, J.W., Holden, M.J. & McConnell, R.M. (1966). Fishery report. In: White E (Ed). The first scientific report of the Kainji Biological Research Team. University of Ile-Ife, Nigeria. p88.
- Banks, J.W., Holden, M.J. & McConnell, R.M. (1967). Phyletic studies of teleostean fishes with a provisional classification of living forms. Bulletin of the American Museum of Natural of Natural History, New York. 4(4), 55-77.
- Barson, M. (2004). The occurrence of *Contracaecum spp* larvae (Nematoda: Anisakidae) in the catfish *Clarias gariepinus* (Burchell, 1822) from Lake Chivero, Zimbabwe. *Onderstepoort J. of Vet. Res.*, 71, 35 -39.
- Bawole, R., Rembet, U.N.W.J., Ananta, A.S., Runtuboi, F., & Sala, R. (2017). Growth , mortality and exploitation rate of *Plectropomus maculatus* and *P . oligocanthus* (Groupers , Serranidae) on Cenderawasih Bay National. *The Egyptian Journal of Aquatic Research*, 0–5. <https://doi.org/10.1016/j.ejar.2017.09.002>
- Beverton R.J.H. & Holt, S.J. (1966). - Manual of methods for fish stock assessment. Part II. Tables of yield function. FAO Fish. Biol. Techn. Pap. 38, 10 (1), 1-67.
- Bhanbhro, R., Memon, K.H., Qun, L., Ursani, T.J., & Ujjan, S.A. (2017). Estimation of growth and mortality parameters of *Oreochromis mossambicus* from indus River Sukkur. Sindh , Pakistan. *Lasbela, U. J.Sci.Techl.*, 6, 100–108.
- Biu, A., Diyaware, M., Yakaka, W., & Rita, D. (2014). Incidence of parasites of *Clarias gariepinus* (Burchell, 1822) caught from Lake Alau, Maiduguri, Borno State, Nigeria. *Nigerian Journal of Fisheries and Aquaculture*, 2(1), 74–80.
- Boulenger, G.A. (1916). Catalogue of the freshwater fishes of Africa in the British museum (Natural History). Vol. IV, Trustees, London, 392.
- Boyd, E.C. (2004). Farm-level issues in aquaculture certification: Tilapia. Report commissioned by WWF-US in 2004. Auburn University, Alabama 36831.
- Brown, M.L., & Guy, C.S. (2007). Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland. 1-29.

- Brown, R.B., Jacobs, A.L. & Peet, K.R. (2007). Species Richness : Small Scale, 1–8. <https://doi.org/10.1002/9780470015902.a0020488>.
- Bukar, T.A. & Gubio, A.K. (1985). The decline in the commercially important species of fish and predominance of *Clarias lazera* in Lake Chad, Fisheries Society of Nigeria 1985 Conference Proceedings, 35-51.
- Bwanika, G.N., Makanga, B., Kizito, Y., Chapman, L.J. & Balirwa, J. (2004). Observations on the biology of Nile tilapia, *Oreochromis niloticus* L. in two Ugandan Crater lakes. *African Journal of Ecology* 42, 93–101.
- Bwanika, G., Murie, D. & Chapman, L. (2007). Comparative age and growth of Nile tilapia (*Oreochromis niloticus* L.) in Lakes Nabugabo and Wamala, Uganda. *Hydrobiologia*, 589, 287- 301.
- Cadima, E.L. (2003). Fish stock assessment manual. FAO Fisheries Technical Paper 393, Rome, 161.
- Chekol, G.T. (2006). Population dynamics and stock assessment of Nile tilapia, *Oreochromis niloticus* L. in the rift valley Lakes of Koka , Ziway and Langano, Ethiopia. Master of Science Course ISATEC, presented to the University of Bremen , Faculty for Biology & Chemistry.
- Chidi, A.U. (1993). *The Yankari Fishes: An Identification guide to one hundred and fifty Nigerian fish species*. Bauchi, Nigeria. Kobi press..
- Chimatiro, S.K. (2004). The biophysical dynamics of the lower shire river floodplain fisheries in Malawi. PhD thesis, Rhodes University.
- Chude, L.A. (1979). Fish and fisheries of Lake Ndalokwu. A flood plain downstream of Kainji Dam, Kainji Lake research institute report, p.10.
- Clifford, H.T. and Stephenson, W. 1975. An introduction to numerical classification. London Academic Press London 229p
- Daddy, F., Abubarkar, A. & Aina, E. (1991). Studies on Tababu Floodplain vegetation and its utilization. NIFFR Annual Report 1990, NIFFR, Nigeria.
- Dadzie, S., Manyala, J.O., & Abou-seedo, F. (2005). Aspects of the population dynamics of *Liza klunzingeri* in the Kuwait Bay, Cybium, 29(1), 13–20.
- Dankishiya, A.S. & Abdulrahaman, K.A. (2007). Check list of fish fauna in Lake Geriyo, Yola, Adamawa State. *Biological and Environmental Science Journal for the Tropics*, 4 (2), 75- 78.
- Dan-kishiya, A.S., Olatunde, A.A. & Balogun, J.K. (2012). Fish species distribution in a domestic water supply reservoir: A case study of lower Usuma Reservoir, Bwari, Nigeria. *Researcher*. 4(2), 56-60. <http://www.sciencepub.net>

- Dan-kishiya, 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. *American Journal of Research Communication*, 1(9), 188–203.
- Dan-Kishiya, A.S. (2013). Length-weight relationship and condition factor of five fish species from a tropical water supply Reservoir In Abuja , Nigeria. *American Journal Of Research Communication*, 1(9), 175–187.
- Dike, N.I., Ezealor, A.U., Oniye, S.J., & Ajibola, V.O. (2013): Pollution studies of river Jakara in Kano Nigeria, using selected physicochemical parameters. *International Journal of Research in Environmental Science and Technology*, 3(4): 122-129.
- Dutta, S., Maity, S., Chanda, A., & Hazra, S. (2012). Population structure , mortality rate and exploitation rate of *Hilsa shad* (*Tenualosa ilisha*) in West Bengal coast of Northern Bay of Bengal , India, 4(1), 54–59. <https://doi.org/10.5829/idosi.wjfm.2012.04.01.6196>
- Dwivedi, A.C. (2012). Stock assessment of fish species *Labeo rohita*, *Tor tor* and *Labeo calbasu* in the Rivers of Vindhyan region, India. *Journal of Environmental Biology*, 33, 261-264.
- Eccles, D.H. (1992). FAO species identification sheets for fishery purposes: field guide to the freshwater fishes of Tanzania. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.
- Efitre, J., & Chapman, L.J. (2016). Age validation , growth and mortality of introduced *Tilapia zillii* in crater Lake Nkuruba , Uganda. *Fisheries Management and Ecology*, 23, 66–75. <https://doi.org/10.1111/fme.12163>
- Ekevwe, A.E., & Bartholomew, M.G. (2015). Quantitative investigation of heavy metals in water samples of River Jakara in Kano State of Nigeria. *International Journal of Innovation in Science and Mathematics*, 5(3), 257-259.
- Fafioye, O.O. & Oluajo, O.A. (2005). Length-weight relationship of five fish species in Epe Lagoon, Nigeria. *African Journals*, Online. www.academicjournal.org/ajb
- Fagade, S.O. & Olaniyan, C.I.O. (1971). The food and feeding interrelationship of fishes of Lagos lagoon. *Journal of Fish Biology*, 5, 205-225.
- Fagade, S.O. (1983). The biology of *Chromidotilapia guentheri* from a small lake. *Arch Hydrobiology*, 97, 60-72.
- Federal Department of Fisheries (FDF). (2008). Publication of the Federal Fisheries Department (FDF), Federal Ministry of Agriculture and water Resources, Abuja, Nigeria. p53.
- Federal Department of Fisheries (FDF) (2008). Fisheries statistic of Nigeria projected human population: fish demand and supply in Nigeria, 2000-2015. p56.
- Ferrier, S. & Guisan, A. (2006). Spatial modeling of biodiversity at the community level. *J. Appl. Ecol.* 43: 393– 404.

- Feu, T. (2004). Population parameters for the six commercial species in Lake Kainji, Nigeria using length frequency data sampled from artisanal fish catches. *Biology of commercial fish species of Lake Kainji, Nigeria*.
- Food and Agricultural Organisation (FAO). (1997). *The state of world fisheries and aquaculture* (FAO, Rome), 24-27.
- Food and Agricultural Organisation (FAO). (1999). *The state of world fisheries and aquaculture 1998*. FAO Rome, Italy, 89-115.
- Food and Agricultural Organisation (FAO) (2005-2012). *Cultured aquatic species information programme. Oreochromis niloticus*. Cultured aquatic species information programme. Rome.
- Food and Agricultural Organisation (FAO). (2014). *Database on introductions of aquatic species*.
- Forese, R. & Pauly, D. (1998). *Fish Base 98 : Concept, design and datasources*, Manila: ICLARM. p66-94.
- Gabr, M.H., & Mal, A.O. (2017). Stock assessment of the lizardfish *Saurida tumbil* (Bloch , 1795) in Jizan fisheries , Saudi Arabia. *The Egyptian Journal of Aquatic Research*, 43(2), 147–153. <https://doi.org/10.1016/j.ejar.2017.05.001>
- Gaston, K.J. (2003). *The structure and dynamics of geographic ranges*. Oxford University Press, Oxford, UK.
- Gaston, K.J & Spicer V.I. (1998). *Biodiversity: an introduction*. Blackwell Science, Oxford, UK.
- Gayanilo, F.C., Sparre, P., & Pauly, D. (1996). *The FAO-ICLARM Stock Assessment Tools II (FiSAT II): Computerised Information Series (Fisheries)*. FAO, Rome, 8, 126.
- Gayanilo, F.C. & Pauly, D. (1997). *The FAO-ICLARM Stock Assessment Tool II (FiSAT II) Reference manual: Computerised Information Series (Fisheries)*. FAO, Rome, 8, 262.
- Gayanilo, F.C., Sparre, P., & Pauly, D. (2002). *The FAO-ICLARM Stock Assessment Tools II (FiSAT II)*. FAO, Rome, 7, 124. URL: <http://www.fao.org/fi/statist/fisoft/fisat/index.htm>
- Gayanilo, F.C., Sparre, P., & Pauly, D. (2005). *FAO-ICLARM Stock Assessment Tools II (FiSAT II). Revised user's guide*. Computerised Information Series (Fisheries). FAO, Rome, 168.
- Getabu, A. (1992). Growth parameters and total mortality in *Oreochromis niloticus* (Linnaeus) from Nyanza Gulf, Lake Victoria. *Hydrobiologia*, 232, 91–97.
- Global Invasive Species Database (GISD) (2012). *-Oreochromis niloticus*: Available from: <http://www.issg.org/database/species/ecology.asp?si=1322&fr=1&sts=sss&lang=EN>
- Gracia, C. B., Buarte, J. O., Sandoval, N., Von Schiller, D. & Mello, N. P. (1998). Length weight relationships of demersal fishes from the Gulf of Salamanca, Colombia. *Fishbyte*, 21, 30-32.

- Guisan, A., Weiss, S.B & Weiss, A.D.(1999). GLM versus CCA spatial modeling of plant species distribution. *Plant. Ecol.* 143: 107–122.
- Gulland, J.A. (1969). Manual of Methods for Fish Stock Assessment Part 1. Fish manipulation analysis. FAO manual in fisheries science, Rome, 4, 154.
- Gulland, J.A. (1971). *The Fish Resources of the Ocean*. West Byfleet Surrey. Fishing News Books, Ltd. for FAO, 255.
- Gulland, J.A. (1982). Why do fish numbers vary? *Journal of Theoretical Biology*, 97, 69–75.
- Gulland, J.A. (1983). Fish stock assessment: A manual of basic methods. Chichester, U.K., Wiley Interscience, FAO/Wiley series on food and agriculture, (1), 223.
- Gulland, J.A. & Rosenberg, A.A. (1992). A review of length-based approaches to assessing fish stocks. FAO Fish Technical Paper, 323, 100.
- Gupta, B.K., Sarka, U.K., & Bharadwa, S.K. (2015). Analysis of morphometric characters and population dynamics of Ompok pabda (Hamilton, 1822) from Gomti River in Northern India. *Journal of Biological Sciences and Medicine*, 1 (1), 49–58.
- Hamoivici, M. & Velasco, G. (2000). Length-weight relationship of marine fishes from Southern Brazil. *Naga, ICLARM Quart*, 23, 19-23.
- Hiddink, J.G., Rijnsdorp, A., Bekkevoold, D., & Ojaveer, H. (2006). Importance of fish biodiversity for the management of fisheries and ecosystems. MarBef Marine Biodiversity and Ecosystem Functioning - EU Network of Excellence, 1–3.
- Hoffman, L.C. & Prinsloo, J.F. (1996). The potential of freshwater fish in South Africa. *Food Industries of South Africa*, 30, 1 – 2
- Holden, M.J. & Reed W. (1972). *West African Freshwater Fish*. London, U.K: Longman.
- Hubbell, S.P. (2001). The unified neutral theory of biodiversity and biogeography. Princeton University Press, Princeton, United States of America. 275.
- Hurtado, E.G., Puelles, R.C.P., Salvador, E., Cota, L., Yanez, A.A.G., Garcia, V.M. & Rosa, R. B. (2005). Historical biomass, fishing mortality, and recruitment trends of the Campeche Bank red grouper (*Epinephelus morio*). *Fish. Res.* 71, 267–277.
- Ibrahim, B.U., Auta, J. & Balogun, J.K. (2009). A survey of the artisanal fisheries of Kontagora Reservoir, Niger State, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 2(1), 47 - 51.
- Ibrahim, B.U., Auta, J. & Balogun, J.K. (2009). An assessment of the physicochemical parameters of Kontagora Reservoir, Niger State, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 2(1), 64 – 69.
- Ibrahim, S. & Said, H.A. (2010). Heavy metals load in tilapia species: A case study of Jakara River and Kusalla Dam, Kano state, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 3(1), 87-90.

- Ikenweiwe, N.B., Otubusin, S.O., Akinwale, M.A. & Osofero, S.A. (2007). A comparison of the composition and abundance of fish species caught with experimental gillnet with that of artisanal fishermen at Oyan Lake, South West Nigeria. *European Journal of Science Res*, 16 (3), 336-346.
- Ikusemiju, K. & Olaniyan, C.I.O. (1997). The food and feeding habits of the catfish *Chrysichthys walkeri* (Gunther), *Chrysichthys filamentosus* (Boulenger) and *Chrysichthys nigrodigitatus* (Lacepede) in Lekki Lagoon, Nigeria. *Nigeria Journal of Fisheries and Aquaculture*, 10, 105-112.
- Imam, T.S., Bala, U., Balarabe, M.L., & Oyeyi, T.I. (2010). Length-weight relationship and condition factor of four fish species from Wasai Reservoir in Kano , Nigeria, *African Journal of General Agriculture*, 6(3), 125–130.
- Imam, T.S. & Dewu, R.A. (2010). Survey of *Piscine* ecto and intestinal parasites of *Clarias sp.* sold at Galadima road fish market, Kano metropolis, Nigeria. *Bioscience Research Communication*, 22(4), 209.
- Indira, R., Prabhu Arachi, J.M.A. & Varadharajan, D. (2013). Studies on the reproductive biology of red jewel, *International Journal of Environmental Biology* 3(4), 160–172. <http://www.urpjournals.com>
- Indira, R., & Pugazhendy, K. (2016). Studies on population dynamics of jewel cichlid *hemichromis bimaculatus* (gill). *International Journal Of Modern Research And Reviews*,4(4), 1139–1143.
- Inuwa, B. (2007). Aspect of physicochemical conditions and the fish biology of Jakara Dam fish species. M.Sc. Thesis, Bayero University, Kano (Kano, Nigeria, 2007)
- Ita, E.O., Balogun, J.K. & Adimula, A.B. (1982). Sokoto Rima River Basin Development Authority: A preliminary report of pre-impoundment fisheries survey of Gronyo Reservoir, Sokoto State, Nigeria.
- Ita, E.O.(1985). Inventory survey of Nigerian inland waters and their fishery resources with special references on Ponds, Lakes, Reservoirs and major Rivers. Kainji Lake research institute technical report series, 14, Kainji, Nigeria.
- Ita, E.O. & Pandogari, A. (1987). A preliminary investigations on the fish and fisheries of some randomly selected Reservoirs in Kano State. Kainji Lake Research Institute. Annual Report, 10, 38-43.
- Ita, E .O. (1993). Inland fishery resources of Nigeria. Central Insitute of Freshwater Aquaculture Occasional Paper, 20: 120-126.
- Jenning, S., Kasier, M. & Reynold, J.D. (2000). *Marine fisheries ecology*. UK: Black well Science Ltd, 391.
- Kapetsky, J.M. & Nath, S.S. (1997). A strategic assessment of the potential for freshwater fish farming in Latin America. COPESCAL Technical Paper. No. 10. Rome, FAO. 128.

- Kevin, L.P., Steve, E.L. & Young, M.K. (1995). Methods for assessing fish populations, 325–352.
- Khaironizam, M.Z. & Norma-Rshid, Y. (2002). Length-weight relationship of Mudskipper in the Coastal Areas of Scangor, Malaysia. *International Centre for Living Aquatic Resources Management: World Fish Centre Quarterly Report*, 25, 20-22.
- King, M. (2007). *Fisheries biology, assessment and management*. London, UK: Fishing News Book, London. 342 pp.
- Kohn, M.C. (1986). Strategies for computer modelling. *Bulletin of Mathematical Biology*, 42, 417- 426.
- Krohne, D.T. (2001). *General ecology*. 2nded. London, UK: Brooks/Cole, London. 512pp.
- Lamai, S.L. and Kolo, R.J. (2003). Biodiversity and abundance of fish and plankton of Dan-Zaria Dam, Niger State, Nigeria. *Journal of Aquatic Science*, 18 (2), 141 – 148.
- Lande, R. (1996). Statistics and partitioning of species diversity, and similarity among multiple communities. *Oikos*. 76, 5 – 13.
- Lawan, I. & Ahmed, A. (2014). Physico-chemical parameters in relation to fish abundance in Daberam Reservoir, Katsina State, Nigeria. *Entomology and Applied Science Letters*, 1 (3), 43-48. <http://www.easletters.com/issues.html> 43
- Lawrence, F.Z. & Sa. K.A. (2015). Some aspect of the biology of *Clarias gariepinus* in coca cola wastewater Reservoir Maiduguri Borno State, Nigeria. *Journal of Biology, Agriculture and Healthcare*, 18(5), 137–144.
- Lawson, O.E. & Olusanya, M.O. (2010). Fish diversity in three tributaries of River Ore, South-West, Nigeria. *Journal of Fish Science*, 2(6), 524-531.
- Legendre, M., Teugels, G.G, Cauty, C. & Jalaber, B. (1992). A comparative study on smorphology, growth rate and reproduction of *Clarias gariepinus* (Burchell, 1822), *Heterobranchus longifilis*^o(Valencienness, 1840), and their reciprocal hybrids (Pisces, Clariidae). *Journal of Fish Biology*, 40, 59-79.
- Lowe-McConnell, R.H. (1975). *Fish Communities in Tropical Freshwaters*. London, UK: Longman, London.
- Maceina, M.J., & Pereira, D.L. (2007). Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.
- Magurran, A.E. (2004). *Measuring Biological Diversity*., Victoria, Australia: Blackwell Publishing Carlton. 256 p
- Mahapatra, B.K., Dutta, A., Basu, A., Dey, U.K., & Sengupta, K.K. (1999). Observation on the spawning and rearing of Angel fish, *Pterophyllunl scaluw* (Lichenstein). *International Journal of Fauna and Biological Studies*, 10(2), 123-125.

- Mahomoud, W.F., Mohamed, A., Amin, M., & Elboray, K.F. (2011). Reproductive biology and some observation on the age , growth , and management of *Tilapia zilli* (Gerv , 1848) from Lake Timsah , Egypt. *International Journal of Fisheries and Aquaculture*, 2(3), 16-26. <http://www.academicjournals.org/IJFA> ISSN
- Malvestuto, S.P. (1996). Sampling the recreational creel. Pages 591–623 in B. R. Murphy and D. W. Willis, editors. *Fisheries techniques*, 2nd edition. American Fisheries Society, Bethesda, Maryland.
- Mangesh, M.B., Felix, S., Mahadevi, S.A., Antony, C. & Gopalakannan, A. (2017). Induced breeding of African Jewelfish *Hemichromis bimaculatus* (Gill , 1862) using gonadotropic signaling molecular analogue WOVA-FH. *Journal of Entomology and Zoology Studies*, 5(6), 2547-2551.
- Marquez, J.L.G., Mendoza, B.P.M., Ugarte, I.H.S. & Figueroa, J.L.A. (2008). Age and growth of the tilapia, *Oreochromis niloticus* (Perciformes: Cichlidae) from a Tropical shallow Lake in Mexico. *Revesta de Biologia Tropical (International Journal of Tropical Biology ISSN-0034-7744)*, 56 (2), 875-884.
- Mayank, P., Rizvi, A.F., & Dwivedi, A.C. (2017). Population dynamics of *Cirrhinus mrigala* (Hamilton 1822) from the largest tributary of the Ganga River , India. *International Journal of Fauna and Biological Studies*, 4(4), 42-47.
- McGill, B.J., Etienne, R.S., Gray, J.S., Alonso, D., Anderson, M.J., Benecha, H.K., Dornelas, M., Enquist, B.J., Green, J.L., He, F., Hurlbert, A.H., Magurran, A.E., Marquet, P.A., Maurer, B.A., Ostling, A., Soykan, C.U., Ugland, K.I. & White, E.P. (2007). Species Abundance Distributions: Moving Beyond Single Prediction Theories to Integration within an Ecological Framework. *Ecology Letters*, 10: 995–1015.
- Miranda, L.E., & Bettoli, P.W. (2007). Mortality. Pages 229–277 in Guy, C. S. & Brown, M. L. editors. *Analysis and interpretation of freshwater fisheries data*. American Fisheries Society, Bethesda, Maryland.
- Montcho, S.A., Agadjihouèdé, H., & Montchowui, E. (2015). Population parameters of *Oreochromis niloticus* (Cichlidae) recently introduced in lake Toho, Benin. *International Journal of Fisheries and Aquatic Studies*, 2(3), 141-145.
- Moreau, J., Bambino, C. & Pauly, D., (1986). A comparison of four indices of overall growth performance based on 100 tilapia populations (Fam. Cichlidae). In: Maclean, J. L., Dizon, L. B., Hosillos, L. V. (Eds.), *The First Asian Fisheries Forum*. Asian Fisheries Society, Manila, Philippines, 201–206.
- Moyle, P.B. & Cech, J.J. (1996): *An Introduction to Ichthyology*. 3rd ed. Printice Hall: New Jersey. 67-122.
- Murugan, S., Rahman, M.A.U., Khan, S.A., & Lyla, P.S. (2014). Growth and population dynamics of Flathead grey mullet , *Mugil cephalus* (Linnaeus , 1758) from Parangipettai waters, Southeast coast of India. *An International Journal of Marine Sciences*, 30(2), 47–56.

- Musa, H., Ya' u, A.A., Hassan, M.I., & Bashir, S.I. (2016). Length-weight relationship , condition factor and stomach contents analysis of *Oreochromis niloticus* in Shirmu Lake Hungu, Kano state, Nigeria. *Global Advanced Research Journals*, 5(7), 315–324.
- Mustapha, M.K. (2008). Assessment of the water quality of Oyun Reservoir, Offa, Nigeria, using selected physico-chemical parameters. *Turkish Journal of Fisheries and Aquatic Science*, 8, 309-319.
- Nafiu, S.A., Badamasi, I., Ahmad, M.K., Abdullahi, M.T., Yelwa, S.I. & Ibrahim, B.A. (2017). Some aspects of fisheries ecology in Thomas Dam , Kano Nigeria. *Bayero Journal of Pure and Applied Sciences*, 10(1), 192–197.
- Nanda, S.N. & Tiwari, T.N. (2001). A survey of fish fauna in the Sambalpur-Hirakund-Burin region, Orissa. *Environment and pollution*, 8(1), 43-44.
- Natural Resources Conservation Council of Nigeria (NARESCON) (1992). Natural resources conservation action plan. Final report. 1, 114.
- Nehemia, A., Maganira, J.D. & Rumisha, C. (2012). Length- weight relationship and condition factor of Tilapia species grown in Marine and Freshwater Ponds. *Agriculture and Biology Journal of North America*, 3(3), 117-124.
- Nelson, M.E., Vallierre, K. & Deleveaux, W. (2007). The Bahamas Nassau grouper (*Epinephelus striatus*) fishery-two assessment methods applied to a data deficient coastal population. *Fish. Res.* 87, 17–27.
- Niamaimandi, N., Kaymaram, F., & Hoolihan, J.P. (2015). Population dynamics parameters of narrow-barred Spanish mackerel , *Scomberomorus commerson* (Lacèpède , 1800), from commercial catch in the Northern Persian Gulf. *Global Ecology and Conservation*, 4, 666–672. <https://doi.org/10.1016/j.gecco.2015.10.012>
- Njiru, M., Okeyo-Owuor, J.B., Muchiri, M., Cowx, I.G. & Knaap, M.V. (2007). Changes in population characteristics and diet of Nile tilapia *Oreochromis niloticus* (L .) from Nyanza Gulf of Lake Victoria , Kenya : what are the management options? *Aquatic ecosystem health & management*, 10(4), 434-442, DOI: 10.1080/14634980701708099
- Novaes, J.L.C. & Carvalho, E.D. (2012). Reproduction, food dynamics and exploitation level of *Oreochromis niloticus* (Perciformes: Cichlidae) from artisanal fisheries in Barra Bonita Reservoir, Brazil. *Revista de Biología Tropical*, 60 (2), 721–734. DOI:10.15517/rbt.v60i2.3987
- Nurul, A.S.M., Srshad, A., Siraj, S.S., Sidik, B.J. (2009). Population structure, growth, mortality and yield per recruit of segestid shrimp *Acetes japonicus* (Decapoda: Sergestidae) from the coastal waters of Malacca, penninsular Malaysia. *Ind J Mar Sci* 38, 57-68.
- Nwadiaro, C.S. (1984). The longitudinal distribution of macro invertebrates and fish in lower Niger Delta River (River Sombrierio). *Nigeria Hydrobiology Bulletin*, 18, 13-40.
- Obasohan, E.E. & Oransaye, J.A.O. (2006). Biodiversity and sustainability of freshwater fishes of Nigeria. *Fisheries Society of Nigeria Proceeding*, 12, 230-237.

- Ogbe, F.G., Obande, R.A. & Okayi, R.G. (2006). Age, growth and mortality of *Bagrus bayad* from Lower Benue River, Nigeria. *Journal for the Tropics*, 3(2), 103-109.
- Ogutu-Ohwayo, R. (2005). The fisheries of Lake Victoria: harvesting biomass at the expense of Biodiversity. <http://www.cbd.int/doc/nbsap/fisheries/ogutu/summary/29pdf>. Retrieved on 20th July 2018.
- Okogwu, O.I. (2011). Age, growth and mortality of *Clarias gariepinus* (Siluriformes : Clariidae) in the Mid-Cross River-Floodplain ecosystem, Nigeria. *Rev. Biol. Trop. (International Journal Tropical. Biology.)* 59 (4), 1707-1716.
- Olaosebikan, B.D. & Raji, A. (2004). *Field guide of Nigeria Freshwater Fishes*. 2nd ed, Ilorin Nigeria: Remi Thomas Printing Press. 115Pp.
- Olatunde, A.A. (1977). The distribution, abundance and trend in the establishment of the family Schilbeidae in Lake Kainji, *Journal of Nigeria Hydrobiology*, 56, 69-80.
- Olopade, O.A. (2010). Observations on fishing methods in Oyan Lake. *African J. Livestock Ext.* 8, 35-39.
- Olopade, O.A., & Rufai, O.P. (2014). Composition, abundance and diversity of the family Cichlidae in Oyan Dam, Ogun State, Nigeria. *Biodiversitas*, 15(2), 195–199. <https://doi.org/10.13057/biodiv/d150211>
- Olurin, K.B. & Aderibigbe, O.A. (2006). Length-weight relationship and condition factor of pond reared juvenile *Oreochromis niloticus*. *World Journal of Zoology* 1(2), 82- 85.
- Olusola, O.K. & Arawomo, G.O.A. (2008). Preliminary observations on fish species in a newly impounded Osinmo Reservoir. *Turkish Journal of Fisheries and Aquatic Science*, 8, 289-292.
- Omowumi, M. (2013). Ichthyofauna diversity of Lake Asejire: Ecological implications. *International Journal of Fisheries and Aquaculture*, 5(10), 248–252. <https://doi.org/10.5897/IJFA13.0379>
- Oniye, S.J., Adebote, D.A., Usman, S.K. & Makpo, J.K. (2006). Some aspects of the biology of *Protopterus annectens* (Owen) in Jachi Dam, Katsina State, Nigeria. *Journal of Fisheries and Aquatic Sciences*, 2, 136-141.
- Oribhabor, B.J. (2016). Review article impact of human activities on biodiversity in Nigerian aquatic ecosystems. *Sci. Int.*, 4 (1), 12-20. <https://doi.org/10.17311/sciintl.2016.12.20>
- Oyewo, S.D. (2015). A survey of fish species diversity and abundance in Dogon Ruwa water body of Kamuku National Park, Birnin Gwari, Kaduna State, Nigeria. M.Sc. thesis submitted to department of biological sciences, Ahmadu Bello University, Zaria, Nigeria.
- Parker, J.O. & Haswell, A. (1964). Age, growth and mortality of *Bagru bayad Macropetrus* (Foskalis, 1775) from lower Benue River, Nigeria. *Biological and Environmental Sciences Journal for the Tropics*, 3(2), 103-109.

- Pauly, D. (1978). A preliminary compilation of fish length growth parameters. *Berichte des Institut für Meerekunde an der Christian-Albrechts Universität Kiel*, 55, 200p,
- Pauly, D. (1979). Theory and management of tropical multispecies stocks: A review with emphasis on the Southeast Asian demersal fisheries stud.
- Pauly, D. (1980). A selection of simple method for the assessment of tropical fish stocks. *FAO* pp: 54. 16. Gulland J (1971): *The Fish Resources of the Oceans*. *FAO/Fishing News Books*, Surrey pp: 255.
- Pauly, D. (1983): Some simple methods for the assessment of tropical fish stocks. *FAO Fisheries Technical paper*, (234), *FAO*, Rome, Italy.
- Pauly, D. (1984). Fish population dynamics in tropical waters: A manual for use with programmable calculations. *ICLARM Stud* pp: 325.
- Pauly, D. & Munro, J.L., (1984). Once more on the comparison of growth in fish and invertebrates. *ICLARM Fishbyte* 2 (1), 21.
- Pauly, D., & Caddy, J.F. (1985). A modification of Bhattacharya's method for the analysis of mixtures of normal distributions. *FAO Fish Circ* pp 16.
- Pauly, D. & Soriano, M.L., (1986). Some practical extension to the Beverton and Holt's relative yield-per-recruit model. In: MacLean, J.L., Dizon, L.B. & Hosillo, L.V. (Eds.), *The First Asian Fisheries Forum*. *Asian Fisheries Society*, Manila, Philippines, p 491–496.
- Pauly, D. (1987). A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates. *The international conference on the theory and application of length-based methods for population assessment*. Italy.
- Pauly, D. & Morgan G.R. (1987). *Length-based methods in fisheries research*. Manila; *ICLARM and Kuwait*; *KISFR*, 468 pp.
- Pauly, D., (1991). Growth performance in fishes: Rigorous description of patterns as a basis for understanding causal mechanisms. *ICLARM Aquabyte*, 4 (3), 3–6.
- Pauly, D. (1993). Fishbyte section editorial, *Naga the ICLARM Quarterly*, 16, 26-27.
- Pauly, D., Christensen, V. & Walters, C. (2000). Ecopath, Ecosim and Ecospace as tools for evaluating ecosystem impact of fisheries. *ICES Journal of Marine Science* ,57, 697-706.
- Philippart, J. & Ruwet, C. (1982). Ecology and distribution of tilapias. *ICLARM Conference Proceedings* 7.
- Picker, M.D. & Griffiths, C.L. (2011). *Alien and Invasive Animals*. Cape Town, South Africa: A South African perspective. *randomhouse/Struik*, South Africa.
- Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology*. 13, 131 – 144.

- Pitcher, T. (1999). Evaluating the benefits of recreational fisheries. *Fisheries Centre Research Reports*, 7(2), 169.
- Possingham, H.P, Lindenmayer, D.B & McCarthy, M.A. (2001). Population Viability Analysis, *Encyclopædia of Biodiversity*. Academic Press, pp 831– 843
- Rabi, S.D. (2018). Current status of *Lymnea* and *Bulinus* species in Wasai part of Jakara dam , Kano state , Nigeria and their public health implications. *Journal of Pharmacy and Biological Sciences*, 13(1), 5–8. <https://doi.org/10.9790/3008-1301050508>
- Ravindra, P.H., Patel, N.G. & Patel, Y.E. (2014). Review on fresh water fish diversity of Maharashtra India . *Journal of Entomology and Zoology Studies*, 2(5), 358–364.
- Reed, W.T., Burchad A.J., Hopson, J., Jenness, J., & Yaro, I. (1967). *Fish and fisheries of Northern Nigeria*. Zaria, Nigeria: Ministry of Agriculture, Northern Nigeria.
- Regan, H.M, Auld, T.D, Keith, D.A & Burgman, M.A. (2003). The effects of fire and predators on the long-term persistence of an endangered shrub, *Grevillea caleyi*. *Biol. Conserv.* 109: 73–83.
- Renjithkumar, C.R., (2014). Fish germplasm resources and exploited fisheries of the kerala and bionomics of 'red canarese barb' *hypselobarbus thomassi*. ph.D theses, school of industrial fisheries Cochin university of science and technology Kochi, Kerala, India.
- Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. *Fisheries Research Board of Canada Bulletin* 191.
- Riede, K. (2004). Global register of migratory species - from global to regional scales. Final Report of the R&D-Projekt 808 05 081. Federal Agency for Nature Conservation, Bonn, Germany.
- Rizvi, A.F., Dwivedi, A.C. & Singh, K.P. (2010). Study on population dynamics of *Labeo calbasu* (Ham.): suggesting conservational methods for optimum yield. *Natl. Acad. Sci. Lett.*, 33(7), 247-253.
- Ross, L.G., Martinez Palacios, C.A., & Morales, E.J. (2008). Developing native fishspecies for aquaculture: The interacting demands of biodiversity, sustainableaquaculture and livelihoods. *Aquaculture Research*, 39, 675-683.
- Reynolds, D.T. (1973). Biology and fisheries potential of four species of *Alestes* (Pisces Characinidae) to the new Volta Lake. *Rev. Zool. Biol. Africanies*, 298- 306.
- Sabet, H.M., Heidari, A. & Paknejad, S. (2016). Length – weight and length – length relationships of genus *Alosa* (Clupeoidei: Clupeiformes: Clupeidae) along the Southern Caspian Sea coast. *J. Appl. Ichthyl.*, 32, 129 – 130.
- Sajan, S., Mercy, T.V.A., & Malika, V. (2015). Age , growth and population dynamics of an endangered fish *Sahyadria denisonii* (Day 1865) from the Western Ghats hotspot of India. *Asian Fisheries Science*, 28, 130-142.

- Sanchez, F.A. (2000). Octopus-red grouper exploited interaction in the ecosystem of the Northern continental shelf of Yucatan, Mexico. *Ecol. Model.* 129, 119–129.
- Schneider, W. (1990). FAO species identification sheets for fishery purposes: Field guide to the commercial marine resources of the Gulf of Guinea. Food and Agricultural Organisation of the United Nations, Rome pp: 268.
- Simpson, E.H. (1949). Measurement of diversity. *Nature.* 163: 688.
- Skelton, P.H. (2001). *A complete guide to the Freshwater Fishes of Southern Africa*. Cape Town, South Africa: Southern Book Publishers, South Africa.
- Sparre, P. & Venema, S.C. (1989). Introduction to tropical fish stock assessment-part 1: Manual. FAO Fisheries Technical Paper No. 306/1, FAO, Rome, Italy, pp: 337.
- Sparre, P., Venema S.C., (1998). Introduction to tropical fish stock assessment. Part 1, Manual. FAO Fisheries Technical Paper. No 306.1, Rev 2. Rome. 407.
- Teichert-Coddington, D.R., Popma, T.J. & Lovshin, L.L. (1997). Attributes of tropical pond-cultured fish, pgs 183-198. In: Enga H.S. & Boyd, C.E.(eds.), *Dynamics of Pond Aquaculture*. CRC Press, Boca Raton, Florida, USA.
- Tembo, F.M. (2004). Population parameters and exploitation rate of *Engraulicypris sardella* and *Rhamphochromis species* in Southern Lake Malawi: Case of light attraction fishery. UNU Fisheries Training Programme, Reykjavik, Iceland.
- Teugels, G.G. (1982). Preliminary results "of- morphological study or fine African species of the subgenus *Clarias* (Pisces. Claridae). *Journal of Natural History*, 16: 439-4.64.
- Teugels, G.G. (2003). The fresh and brackish water fishes of West Africa. *Journal of Natural History*, 2, 521- 600.
- Thomas, J., Vena, S. & Kuruo, B.M. (2003). Length-weight relationship of some deep sea fish inhabiting the continental slope beyond 250m depth along the West Coast of India. *World Fish Centre Quarterly Report*, 26: 17-21.
- Trewavas, E. (1983). *Tilapiine fishes of the genera Sarotherodon, Oreochromis and Danakilia*. New York: British Museum of Natural History Publication. Comstock Publishing Associates, Ithaca, New York.
- Udoh, J.P., Brownson, I., Udo, M.T., & Ofor, C. (2013). Population dynamics Of Mudskipper , *Periophthalmus barbarus* (Linneaus 1766) (Teleostei : Gobiidae) in the artisanal fishery of Imo River Estuary ,Southeast Nigeria. *Journal of Fisheries and Aquaculture*, 4(3), 148–153.
- Uneke, I.B., & Nwani, C.D. (2014). Stock assessment of *Tilapia zilli* in a Nigerian Tropical River Basin. *Journal of Zoology and Ecology*, (10), DOI:10.1080/21658005.2014.959283

- United Nation Development Programme (UNDP). (2010). Human development report 2010, the Real wealth of nations: path ways to human development. 20th Anniversary edition. Palgrave Macmilan New York. 236Pp.
- Vrijenhoek, R.C. (1998). Conservation genetics of freshwater fish. *J. Fish Biol.*, 53, 394– 412.
- Wang, J., Lu, B., Zan, R., Chai, J., Ma, W., Jin, W., Duan, R., Luo, J., Murphy, R. W., Xiao, H. & Chen, Z. (2016). Phylogenetic relationships of five Asian Schilbid genera including *Clupisoma* (Siluriformes: Schilbeidae). *PLoS ONE*,11(1), e0145675. doi: 10.1371
- Wehye, A.S., & Amponsah, S.K. (2017). Growth , mortality and exploitation rates of Lesser African threadfin , *Galeoides decadactylus* (Bloch , 1795) within the coastal waters of Liberia. *International Journal of Fisheries and Aquatic Research*, 2(2), 43–49.
- Wehye, A.S., Ofori-danson, P.K., & Lamptey, A.M. (2017). And their implications for management and conservation within the coastal. *Fisheries and Aquaculture Journal*, 8(2). <https://doi.org/10.4172/2150-3508.1000201>
- Welman, J.B. (1984). The Physico-chemical hydrology of a Tropical seasonal River, upper Ogun River. *Journal of Nigeria Hydrobiology*, 79, 157-165.
- Wells, J.V., & Richmond, M.E. (1995). Populations, metapopulations, and species populations: what are they and who should care? *Wildlife Society Bulletin* 23, 458–462.
- Whittaker, R.H (1972) Evolution and measurement of species diversity. *Taxon* 21: 213–251.
- Williams, M. (1996). The transition in the contribution of living aquatic resources to food security, food,agriculture and the environment. Discussion paper 13 of the International Food Research Institute,Washington, D.C., pp. 3-24.
- Wootton, R.J., (1998). *Ecology of Teleost Fishes*. (2nd ed.). London, U. K: Chapman and Hall, London, U. K. pp. 27-62.
- World Bank, 1992. A study of international fisheries research. World Bank (International Bank for Reconstruction and Development), Washington DC. USA, Policy and Research Series, (19), 103.
- WRECA (1974). Hydrological survey of North East Kano State planning programme
- Yahaya, M.N., Umar, F.G., Jibrin, D.M. & Idris, U.D. (2015). Assessment of water quality of River Minjibir for irrigation purposes in Kano State , Nigeria. *Nigerian Journal of Agriculture, Food and Environment*, 11(3), 97-101.
- Young, G.L. (1962). *Fundamentals of Ecology*, W. B. Saunders, Philadelphia, Pennsylvania, United States of America, pp. 52-80.