DETERMINATION OF WATER QUALITY AND PROXIMATE COMPOSITION OF FRESHWATER CRAB (SUDANONAUTES KAGOROENSIS, CUMBERLIDGE, 1991) OF KUBANNI RESERVOIR, ZARIA, NIGERIA

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JULY, 2015.

TITLE PAGE

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P13SCBS8045

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER DEGREE IN EDUCATIONAL BIOLOGY

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JUNE, 2015

DECLARATION

I hereby declare that the work in this thesis entitled **''DETERMINATION OF WATER QUALITY AND PROXIMATE COMPOSITION OF FRESHWATER CRAB *(SUDANONAUTES KAGOROENSIS,* Cumberlidge, 1991*)* OF KUBANNI RESERVOIR, ZARIA, NIGERIA"** was carried by me in the Department of Biological Sciences, under the supervision of Prof. D.S. Abolude and Dr. M.A. Adelanwa. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis has been presented for another degree or diploma at any institution.

Aisha USMAN	_____	_____
Name of student	Signature	Date

CERTIFICATION

This thesis entitled **''DETERMINATION OF WATER QUALITY AND PROXIMATE COMPOSITION OF FRESHWATER CRAB *(SUDANONAUTES KAGOROENSIS*, Cumberlidge, 1991*)* OF KUBANNI RESERVOIR ZARIA, NIGERIA"** by Aisha USMAN meets the regulations governing the award of degree of Master of Science in Educational Biology of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ACKNOWLEDGMENTS

I am most grateful to my Creator for sparing my life to this moment and for giving me good health, mental balance and vitality to carry out this work successfully.

My special thanks go to my supervisors Prof. D.S. Abolude for assisting with suggestions, relevant information and for taking his time off to illustrate the manner in which the sampling was conducted. Also great thanks go to Dr. M.A Adelanwa for his constructive criticism to the scheme and completion of this work. To you all, I say God bless you.

I am especially grateful to the Head of Department and the technical staff of the Department for the assistance they rendered me throughout the work. May Almighty God bless you all, Ameen.

My warmly thanks go to Prof. S. A. Abdullahi for the numerous support and assistance rendered during the course of this work. May the Almighty reward you Sir.

My sincere appreciation goes to my late husband (Barrister Bala Usman) for permitting me to undergo this program (May his soul rest in perfect peace amin). Mal.Yunusa Wada, I am in every way grateful for your assistance and efforts in all regards. May the Almighty grant you more knowledge, wisdom and whatever your heart desires, Ameen.

ABSTRACT

Investigation into some aspects of the water quality and proximate composition of freshwater crab *sudanonautes kagoroensis* (Cumberlidge, 1991) in kubanni Reservoir, Zaria, Kaduna State, Nigeria was carried out between February and August 2010 using APHA and AOAC standard methods. Analysis of Variance (ANOVA) was used to compare the means of the physico-chemical parameters. Moisture, ash, fat, protein and carbohydrate content of the various component parts were first analysed by one-way analysis of variance (ANOVA).Where a significant difference ($P \leq 0.5$) was observed, Duncan Multiple Range Test was used to separate the means. Students T Test was used to test for significance in the condition factor of *Sudanonautes kagoroensis* between sexes with respect to seasons. The study revealed that the mean values of air temperature were ($29.57^{o}C \pm 0.26$ and $28.89^{o}C \pm 0.24$),water temperature ($28.57^{o}C \pm 0.26$ and $26.78^{o}C \pm 0.19$), dissolved Oxygen (6.49 ± 0.15 mgL^{-1} and $6.78 \pm 0.11 mgL^{-1}$), electrical conductivity ($164.33 \pm 2.75 uScm^{-1}$ and $67.20 \pm 2.59 uScm^{-1}$), Water hardness ($65.39 \pm 1.27 mgCaCO_3L^{-1}$ and $69.95 \pm 1.15 mgCaCO_3L^{-1}$), alkalinity ($59.03 \pm 0.75$ $mgCaCO_3L^{-1}$ and 43.93 ± 1.14 $mgCaCO_3L^{-1}$), pH (10.07 ± 3.01 and 7.03 ± 0.07), $P0_4^{-}P$($3.20 \pm 0.12 mgL^{-1}$and $3.86 \pm 0.12 mgL^{-1}$) No_3-N ($2.63 \pm 0.11 ugL^{-1}$ and $2.74 \pm 0.11 mgL^{-1}$) and TDS (68.83 ± 1.17 $mgL^{-1}$and 43.67 ± 1.66 mgL^{-1}) for dry and wet seasons respectively. Significant difference ($P \leq 0.05$) was observed in the mean values of water temperature, electrical conductivity, hardness, phosphate phosphorus and total dissolved solids. There was no significant difference ($P \geq 0.05$) in the air temperature, dissolved oxygen, alkalinity, pH and nitrate nitrogen. The study revealed that the water quality parameters was in the range of W.H.O recommended standard for the survival of aquatic organisms. It also revealed that crab was wide spread and abundant across the various stations of the reservoir. Abundance in terms of number was more during the wet season (140) than dry season (95), with maximum peak in the months

of July and August (49 and 47) respectively. The Condition Factor (K) revealed that crab species were in good health condition. The male to female ratio showed that the females were greater in number than the males in the months of April, June, July and August. While the months of February and March had a higher male to females ration. The proximate composition analysis of crab revealed significant difference ($P \leq 0.05$) in protein and lipid contents of the various body parts analyzed. There was no significant difference ($P \geq 0.05$) in the carbohydrate, ash, and moisture contents of species from different locations. It is concluded that *S. kagoroensis* contained appreciable amounts of protein in line with WHO recommended values to be incorporated into human diet.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The use of marine resources for human consumption has improved rapidly worldwide. In general, seafood products, which include crustacean and shell fish have been recommended for their health supporting characteristics. Shellfish are nutritionally precious sources of various minerals and high quality protein (Skonberg and Perkins, 2002). Crabs, among numerous other invertebrates are considered as an essential shell fishery product (Nalan and Yerlikayaa, 2003). Majority of these aquatic fauna are also found in the tropical freshwaters, where they occupy unique position in the agricultural sectors. It has been claimed that sea animals may contribute 40% of animal protein for average Nigerian (Bradburg and Hollowsy, 1995).

Crustaceans constitute important nutritional component in the diet of rural and urban communities in Nigeria (Fasakin *et al*., 2000) while some species are widely distributed, others are found in restricted areas and they are regarded as delicacies. Majority of crustaceans live in fresh water and the oceans have an immense population. The larger members of this class are the crabs, lobsters, shrimps, crayfish and barnacles (Fasakin *et al*., 2000).

In certain areas of the world, crustaceans are important items in human diet (Fasakin *et al.*, 2000). For example fresh water crabs are consumed by the natives of South America to improve health and to heal physical injuries (Yeo *et al;* 2008).Over 90% of crustaceans consumed in Nigeria are obtained from coastal artisanal and freshwater fisheries (FAO and UNDP, 1989).The chemical composition and nutritional properties of aquatic crustaceans are important in their uses as sources of protein to significant proportion of the world population,

particularly in developing countries where larger animal protein is expensive and beyond the reach of the poor man (Bello-Olusoji and Oke, 2006). Most people rate the fish higher in preference to the crabs which are considered inferior and food for the low income earners/poor. However, it is reported that the crabs make up about 20% of all marine crustaceans caught worldwide; with an estimated 11.2 million tones of it being speculated to be consumed annually (Donaldson and Cullenberg, 1999; Andrea Cohen, 2006).

It was reported that malnutrition affects millions of people all over the world especially in developing nations. Under-nutrition for the poor people and over-nutrition for the rich segment of the population are two parallel forms of malnutrition affecting the nations (Weinberger and Swai, 2006). Over-nutrition is associated with nutritional transition which is due to urbanisation as city dwellers consume mostly refined and junk food ignoring the traditional unrefined food such as fruits and vegetables (Vainio-Maltila,2000; Weinberger and Swai, 2006; Ganry, 2008). This transition leads to increased risk of non-communicable diseases such as diabetes, hypertension, obesity, cancer and cardiovascular diseases. World Health Organization (WHO, 2002) projected that the percentage of people living with diabetes in developing countries may increase to more than two-folds from 115 million in 2000 to 284 million (about 250% increment) in 2030 (Weinberger and Swai,2006).

On the other hand, under-nutrition is the major public health problem affecting the developing countries (Müller and Krawinkel, 2005). According to Dangoggo *et al*; (2012), the World Health Organization (WHO, 2000) estimated that 200 million people in Sub-Sahara Africa are affected with chronic under nutrition. Malnutrition is responsible for over 60% of maternal and infant mortality in Nigeria and 41% of children less than five years are chronically malnourished (Onimawo, 2010). Nigeria was also reported to be the leading

country in Africa and 3rd in the world with chronically undernourished children, over 10 million (Onimawo, 2010).

Animal protein intake by Nigerians has been very low in recent times due primarily to decrease in per caput animal production and rising growth in the human population. According to Animal Research International (2004), crabs are a rich source of omega-3 fatty acids that are essential for lowering triglycerides and blood pressure, apart from reducing the risk of cardiovascular diseases. In addition, these fatty acids facilitate in reducing inflammation, increasing the supply of HDL (High Density Lipids) cholesterol, preventing blood clotting and strengthening resistance to infections. The presence of chromium in crabs works with insulin for the metabolism of sugar, thereby helping in maintaining normal blood glucose levels in the body (Animal Research International, 2004). Crab meat is low carbohydrate which makes it a considerable choice for diabetics. Crabs are also a good source of selenium, which aids in reducing oxidative damage to cells and tissues. This mineral, found in crabs acts as an antioxidant by cancelling out the carcinogenic effects of cadmium, mercury and arsenic, known to cause tumours. The higher the levels of selenium, the lower are the risks of cancer (Animal Research International, 2004). It is valuable in the diet because apart from supply of good quality protein and vitamins A and D, it also contain several dietary minerals such as calcium and iron etc. which are beneficial to humans and animals (Abulude *et al.,* 2006).

Water quality is defined in terms of the chemical, physical and biological contents of water. The water quality of rivers and lakes changes with the seasons and geographic areas, even when there is no pollution present. Water quality guidelines provide basic scientific information about water quality parameters and ecologically relevant toxicological threshold values to protect specific water uses. Important physical and chemical parameters influencing

the aquatic environment are temperature, rainfall, pH, salinity, dissolved oxygen, carbon dioxide, total suspended and dissolved solids, total alkalinity and acidity and heavy metal contaminants.

These parameters are the limiting factors for the survival of aquatic organisms (flora and fauna). Poor water qualities may be caused by low water flow, municipal effluents and industrial discharges (Chitmanat and Traichaiyaporn, 2010).

1.2 Statement of the Research Problem

Malnutrition is a major health problem in Africa, despite government's efforts to promote food production. Protein-energy malnutrition in infants and children is one of the most common nutritional problems. (Achu, 2004). Developing nations are devastated by hunger and diseases even though the nations have abundant freshwater and other natural resources which if properly used could solve these problems. (Vainio - Maltila, 2000).Documented information is scarce on the food value of most edible crabs in Northern Nigeria despite the nutritive value of these gastropods. Most limnological studies are based on the physico-chemical qualities of water with regards to the species of fish found in the aquatic ecosystem. Information on the proximate composition of crab species found in such ecosystems is scanty, despite the fact that they are considered as shell fish (Moronkola *et al*., 2011) and are therefore consumed by man as protein supplement.

1.3 Justification of the Study

Human beings require food to grow, reproduce and maintain good health. Without food, our bodies could not stay warm, build or repair tissues or maintain a heartbeat. Eating the right foods can help us void certain diseases or recover faster when illness occurs. These and other important functions are fueled by chemical substances in our food called nutrients (Worthington–Robberts, 2008). Though the nutritional composition of numerous

commercially harvested species of crab has been partially described, no work on the nutritive composition of fresh water crab *(Sudanonautes kagoroensis)* with regards to water quality for their survival in Kubanni reservoir has been carried out. Since crabs are good sources of nutrients in human diet in the face of animal protein scarcity, determining their proximate composition and water quality will be of great importance to human health.

1.4 Aim of the study

The aim of this study was to examine the water quality and determine the proximate composition of fresh water crab *(Sudanonautes kagoroensis)* in Kubanni reservoir, Zaria, Nigeria.

1.5 Objectives of the Study

The specific objectives were:

i. To determine the seasonal variations in water quality of Kubanni reservoir.
ii. To determine the crab abundance in Kubanni reservoir.
iii. To determine the seasonal mean condition factor of *Sudanonautes kagoroensis* in the reservoir.
iv. To determine the proximate composition of the body components (claws, dorsal carapace, ventral carapace and walking legs) of *Sudanonautes kagoroensis* in kubanni reservoir.

1.6 Research Hypotheses

i. There is no significant variation in water quality between seasons in Kubanni Reservoir.

ii. There is no significant difference in the crab abundance between seasons and among the various sampling stations of Kubanni reservoir

iii. There is no significant difference in the seasonal mean condition factor of *Sudanonautes kagoroensis* of Kubanni reservoir.

iv. There is no significant difference in the proximate composition of the various body components S*udanonautes kagoroensis* of Kubanni reservoir.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Freshwater Crabs

Fresh water crabs are essential to many fresh water ecosystems, some feed on fallen leaves and algae while other species help circle nutrients by eating vast quantities of detritus. They are the most ecologically important macro invertebrates in tropical inland waters and they help to maintain the long term health of tropical aquatic ecosystem: they are excellent indicators of good water quality (Cumberlidge, 1999).

They are the main catch for small scale fisheries in many parts of the tropics and often provide the primary source of protein for the people (Cumberlidge, 1999). Fresh water crabs in the inland waters of Nigeria belong either to the genus *Sudanonautes* or genus *Potamonautes*. Out of 42 species of crabs, so far identified in Nigeria (Egborge, 1993), *Sudanonautes* species are the most common in fresh waters.

Until now six species of Nigerian freshwater crabs were assigned to the genus *Sudanonautes* (Cumberlidge 1989 and1991). The original description of this genus recognized only three species, S, *africanus, S. aubry* and *S. decazei* and five taxa. There was the recognition of *orthostylis* (Cumberlidge 1989), *monodi,* and *floweri* as full species of *Sudanonautes* (Cumberlidge, 1991). The description of *S. kagoroensis* brings to seven the total of species of *Sudanonautes* known from Nigeria.

2.2 Systematic

It belongs to the Superfamily *Potamoidea,* Family *Potamonautidae*, Genus *Sudanonautes, Sudanonautes kagoroensis(* Cumberlidge,1991*).*Based mainly on the holotype from the Agban River .***Carapace***:* Texture smooth, no granules visible even under magnification; cervical groove faint, cardiac, semicircular grooves deep. Cephalothorax ovoid, rounded, widest at anterior third,

lacking large pointed teeth, somewhat flattened (CT/CW = 0.31), maximum depth in anterior region, Carapace length more than two-thirds carapace width (CL/CW = 0.67). Anterior margin of front indented in middle, curving sharply under; front wide, less than one-third carapace width (FW/CW ~ 0.27). Postfrontal avy, unbroken, curving downward at each end, meeting epibranchial tooth, midgroove short, forked, deep. Exorbital tooth blunt, tow; intermediate tooth reduced to tiny notch; epibranchial tooth almost undetectable. Anterolateral margin of carapace smooth, with faint low teeth visible only under magnification.Posterior margin of carapace curving inward, forming continuous unbroken curve with anterolateral margin. Posterior margin about two-thirds as wide as widest point of carapace (Cumberlidge, 1991).

Distal segment of mandibular palp in one piece, not bifurcated, of potamonautid type; tuft of hairs at junction between distal segment and penultimate segment. Third maxiliipeds with inner margins touching, merus broad, filling entire oral field except for oval efferent respiratory openings, distinct vertical groove on ishium, long flagellum on epipodite (Cumberlidge, 1991). Lateral and longitudinal flank grooves deep, distinct, dividing flanks into three parts; longitudinal flank groove beginning beneath orbit, curving posteriorly across flanks; lateral flank groove beginning at epibranchial corner, curving forward beneath intermediate tooth, joining longitudinal flank groove. Abdomen relatively broad, widest at third segment. First sternal groove deep, distinct, second sternal groove marked only by two deep notches at outer ends (Cumberlidge, 1991).

Gonopods*:* Gonopod 1 end segment beginning as straight continuation of penultimate segment, then curving outward at halfway point, relatively long, almost half length of penultimate segment (ratio end to penultimate segment 1:2,2), terminating in upcurving pointed tip. Viewed from lateral aspect, middle section of end segment distinctly widened at inner margin. Longitudinal groove beginning at junction between two segments, ending at about two-thirds length of end segment; penultimate segment slim, not greatly widened; deep longitudinal groove on inner surface for

reception of gonopod 2 meeting longitudinal groove of end segment at junction between segments. Gonopod 2 shorter than gonopod 1 (reaching only junction between segments of gonopod 1); end segment of *Sudanonautes* type; extremely short, about one-thirteenth as long as penultimate segment (1:13.4); not solid, sides thin, folded inward, inclosing inward-facing hollow; tip rounded; penultimate segment widest at base, tapering sharply inward about one-third along length, last two-thirds forming long, thin, upright process supporting end segment (Cumberlidge, 1991).

Chelae: Right chela of adult male slightly longer (50.0 mm) than left (44.5 mm), two moderate teeth on prehensile edge of dactylus bracketing similar teeth on index. Left chela more slender, smaller than right, showing no large teeth, closed fingers almost touching, not enclosing space; tip of dactylus overlapping tip of immovable finger when chela closed; small longitudinal gap between closed fingers; cutting edges of fingers with small but distinct teeth over entire length; first tooth on carpus of both chela large, tapering, pointed; second carpal tooth small, low, blunt, almost absent, another low tooth visible behind; inner and outer margins of merus of right chela distinctly serrate (Cumberlidge,1991)

Walking legs: Slender, proportions of various segments of different walking legs similar (Cumberlidge, 1991).

Colour: Based on living adult specimens of *S. kagoroensis.* Dorsal carapace and postfrontal crest dark brown; flanks pale brown. Branchial regions of carapace marked by distinct pale yellow patches. Third maxllipeds pale brown with purple tinge; epistome orange-red; cornea black. Sternum pale brown to yellow. Arthrodial membranes between joints of chelae and pereiopods pale white-yellow, Ventral surface of chelae pale brown to pink-mauve, chela teeth yellow; tips of chelae yellow-cream. Pereiopods uniformly light brown. In life,

females and juveniles lack pale yellow patches on dorsal carapace. Specimens preserved in alcohol uniformly light brown, regardless of sex and age (Cumberlidge, 1991).

2.3 Distribution

The species name *kagoroensis* refers to Kagoro, Kaduna State, Nigeria, where the new species was first collected. *Sudanonautes kagoroensis*is locally common in streams and rivers of the guinea savanna zone of west-central Nigeria on the western slopes of the Jos plateau. The species occurs in rivers on the top of the plateau, in the fast-flowing streams that drain the western escarpment, and in rivers close to the western base of the plateau. All seven localities from which *S, kagoroensis* has been collected are associated with the Mada River, which collects water from the Jos plateau and eventually joins the Benue and Niger rivers (Cumberlidge, 1991). *Sudanonautes kagoroensis* has not been recorded in collections of freshwater crabs made in other parts of Nigeria. For example, S. *kagoroensis* is not known from the Sudan savanna zone in northern Nigeria (Cumberlidge, 1986,1991), The species is absent from collections made in the Hadejia-Jama'are river basin in Kano State, tributaries of which rise on the eastern escarpment of the Jos plateau and flow northeast into Lake Chad. *Sudanonautes kagoroensis* is also absent from the Sokoto River, tributaries of which rise on the northwest escarpment of the Jos plateau (Cumberlidge 1985b). Furthermore, S. *kagoroensis* has not been recorded from the tropical rain forests of southeast Nigeria, despite regular surveys of the decapod fauna in that area over a number of years (Cumberlidge 1989).

2.4 Nutritional Facts about Crabs

The chemical composition and nutritive value of crab meat have been extensively investigated in various parts of the world. Crab is highly nutritious and healthy owing to its protein content, unsaturated fatty acids, carbohydrate and mineral composition (Moronkola *et al*., 2011, Broughton *et al.*, 1997). It is reported that the shells and tissues of some crabs,

contain more than 20 different types of amino acids and that crab meat can provide all the needed amino acids for growth (FAO, WHO/ UNO 1985). Their fatty acid component constitutes the best among the aquatic and most desired for development (Cikrikci, 1995). Crabs are a rich source of omega-3 fatty acids that are essential for lowering triglycerides and blood pressure, apart from reducing the risk of cardiovascular disease. In addition, these fatty acids facilitate in reducing inflammation, increasing the supply of HDL cholesterol, preventing blood clotting and strengthening resistance to infections (Animal Research International, 2004).

The presence of chromium in crabs works with insulin for the metabolism of sugar, thereby helping in maintaining normal blood glucose levels in the body. Crab meat is carbohydrate-free which makes it a considerable choice for diabetics (Animal Research International ,2004). Crabs are also a good source of selenium, which aids in reducing oxidative damage to cells and tissues. This mineral, found in crabs, acts as an antioxidant by cancelling out the carcinogenic effects of cadmium, mercury and arsenic, that are known to cause tumors. Higher the levels of selenium, lower are the risks of cancer (Animal Research International, 2004). Majority of the seafood have high concentrations of mercury, which are harmful for health. Fortunately, crabs are low in mercury content, blue crabs in particular thereby making it edible (Kucukgulmez *et al*., 2006). Crab makes excellent seafood for health conscious individuals, who control their calorie intake. Four ounces of crab meat gives only 98 calories and 2 grams of fat (Animal Research International, 2004).

Apart from being low in calories, crabs provide sufficient amounts of protein. For athletes and bodybuilders, they are good choice of protein. Crab meat contains several essential vitamins and minerals, such as vitamin B12, which are necessary for proper nerve function. These crustaceans are rich in the minerals, zinc and copper, which are important for various

vital bodily functions. The potassium content in crab promotes the growth of healthy cells while sodium helps in regulating blood pressure (Animal Research International,2004). Crabs have been successfully used as another better source of food nutrients to man compared to land animals (Fasakin and Merce, 1992). Moisture, dry matter, protein, lipids, vitamins and minerals are the most important components that act as sources of nutritive value of meat (Steffens, 2006).

Quantifying proximate composition is important in ensuring the requirements of food regulations and commercial specifications. Moisture content of flesh is a good indicator of its relative content of energy, protein and lipid (Aberoumad and Pourshafi, 2010). Adeyeye and Ogunlade (2006) studied the proximate and mineral composition of whole body flesh and exoskeleton of male and female common West African fresh water crabs *Sudanonautes africanus africanus* on a dry weight basis. In the exoskeleton and flesh, the protein, fats, percentage utilizable energy due to protein and metabolizable energy were all of higher concentration in male than in female.(Bilgin and Zeliha, 2011) studied the nutritional properties (in relation to season and sex) of fresh water crab (*Potamon potamios*) captured from the lake Egirdir (Turkey). According to the analysis, there was no significant difference in the moisture, protein, fat and ash contents in terms of seasons. But there was significant changes ($P<0.05$) between male and female crab meat in terms of protein values. It was found that fresh water crab meat was a good protein source.

Moronkola *et al.*(2011) studied the proximate and mineral content of crab (*Callinectes amnicola*) living in the shore of Ojo River, Lagos Nigeria and reported that the crude protein ranged between 19.2 – 28.3g / 100g and the study showed that the crab sample were rich in protein with highest observed in crab tissue (28.00 ± 0.071%) while the walking legs are (19.233 ± 0.066%) and the crunchy (19.820 ± 0.069) respectively. The crude fibre and crude

fat ranged from 0.02 – 11.70% and 0.6 – 1.020%. The crude fibre is higher in the walking legs with a value of 11.070% ± 0.037% compared to tissue and the crunchy part with a value of 0.023 ± 0.071% and 6.680 ± 0.074% respectively. The moisture content ranged from 67.37 ± 0.226% to 70.046 ± 0.049% in all the parts analyzed. Ash content recorded an average value of 1.040 ± 0.017%, 1.300 ± 0.001% and 1.041% ± 0.002% in crunchy, walking legs and tissue respectively. Jimmy and Arazu (2010) studied the proximate and mineral composition of two Edible crabs *Callinectes amnicola* and *Uca tangeri*, of the Cross River, Nigeria and reported that the moisture content of the specimens was high giving 72.31 ± 0.96% and 74.54 ± 0.03% for the flesh of .*U. tangeri and C. amnicola* respectively, while the moisture determined in the shell was not significant (P>0.05) with the protein level of .*U. tangeri* being higher than that determined in *C. amnicola*. But the total protein level of *C. amnicola* (flesh and carcass) was 25 ± 3.55 which was higher than that measured in *U. tangeri* by 2.23%. Other proximate parameters which were measured in *C. amnicola* were higher and showed no significant differences (P>0.05) between themselves.

2.5 Physico-Chemical Qualities of Water

Water covers seven-tenth of the earth's surface, and most of this is the oceans (97.2%). Fresh water is just 0.009% of the total earth's waters (Leopold, 1974). Nigeria is blessed with vast expanse of inland fresh water ecosystem, the full extent of this natural endowment has been investigated at various levels of distribution by many researchers (Ita et al; 1985). A compilation of the extent, of fresh water in Nigeria including wet land was estimated at 7,434, 100 ha representing about 3.4% of the total area of Nigeria (Ita, 1993). Determining the physico-chemical qualities of water is an insight into why problems occur and help to discern the trend of water problems as well as their potential remedies. (Adakole *et al.*, 2003) suggested the monitoring of physico-chemical characteristics of water bodies for both long and short term periods to assess the quality distribution and productivity levels of organisms

in water body which depend on physico-chemical and biological characteristics. The population density of organisms in any water system such as inland fresh water and lakes vary considerably according to physico-chemical factors (Saad *et al*., 1990). These factors include Hydrogen ion concentration (pH), Dissolved Oxygen, temperature, electrical conductivity and nutrient (Awanda, 1987). In Unpolluted rivers lakes and seas, the total number of species of organisms is fairly high, this is a result of the diversity and balanced living condition which exist and are characteristics of many water bodies (Awanda, 1987).

2.5.1 Temperature

Temperature plays a very important role in influencing other water quality parameters, distribution and abundance of aquatic organisms (Awanda, 1987). It is one of the factors affecting the metabolic rate of invertebrates. Metabolic rate of an animal tends to increase with increasing temperature (Inyang and Nwankwo, 2004). (Willoughby, 1976) pointed out that increased temperature lowered dissolved oxygen concentration and that the biological significance of the variation in oxygen solubility which was dependent on water temperature, is that plants and animals that respire aerobically may come under stress in warmer water.

Temperature influences the growth and development of plants and other organisms to a large extent (Awanda, 1987). (Jonasson *et at*., 1990) reported that the main abiotic factors which determine the suitability of an environment were temperature and dissolved oxygen.

2.5.2 Dissolved Oxygen

Dissolved Oxygen which most organisms depend on for their existence, decreases with increase in aquatic temperature. It is one of the most important water quality indicators. The dissolved oxygen reflect the general level and health of a water system and the capacity of the water to support a balanced aquatic habit (Awanda, 1987). Sudden and gradual depletion in dissolved oxygen can cause major shift in the kind of aquatic organisms from pollution

intolerant species to pollution tolerant species (Goldman and Horne, 1987). When dissolved oxygen levels are low in any water media, the propagation of fish and other aquatics aerobic life tend to be impaired and large mortalities of organism may occur (Awanda, 1987). Decrease in oxygen concentration, can be attributed mostly to respiration by plant, animals and abiotic bacterial decay (Cole, 1979).The dissolved oxygen content of water results from photosynthesis and respiratory activity of the biota in the open water and the benthos, the diffusion gradient of air and water interface and distribution by wind (Lind, 1979).

2.5.3 Hydrogen ion Concentration (pH)

The hydrogen ion concentration (pH) is an important factor in determining aquatic productivity and the behaviour of invertebrates (O' Brien and de Noyelles 1972; Awanda, 1987). It is the measurement of the acidity or alkalinity of the water system (Awanda, 1987).The principal system regulating pH in natural water is the carbonate system which is composed of carbon dioxide, carbonic acid, bicarbonate and carbonate ions (Wetzel, 1975).Water contains both $H^{\pm}$ (Hydrogen ions) and OH^{-} (hydroxyl ions). If a water sample contains more $H^{\pm}$ than OH^{-} ions, it is considered acidic, if on the other hand it contains more OH^{-} ions than $H^{\pm\ ions}$, it is considered basic. Temperature and solar radiation accelerates photosynthesis which in turn increases carbon dioxide absorption altering the bicarbonate equilibrium and producing OH^{-} ions, thus raising the pH (Chapman and kimstach, 1996).Pure clean water is weakly dissociated and neutral in reaction that is $H^{\pm}$ and H^{-} ions are present in equal proportion. The effects of PH on the chemical, biological and physical properties of a water system make its studies crucial to the lives of the organisms in the medium. (Awanda, 1987). Boyd (1988) showed that the desirable pH range for fish production is 6.5-9.0.

2.5.4 Electrical Conductivity

It is the ability of a body of water to receive and conduct electrical current. It is the measure of the total amount of ions present in a water body and is useful approximation to chemical riches (FAO, 1985 and Awanda, 1987). These ionic pollutant particles are dissolved in the water body not suspended. This dissolved nature of particles gives a high electrical conductivity of the water solution depending on the type of particles (Awanda, 1987). Electrical conductivity was lower in the rainy season than in the dry season, this may be due to dilution of the water. The gradual rise in conductivity as the dry season progressed could be due to the concentration of ions as the volume decreases Balarabe (1989). Conductivity is a general indicator of water quality. Chapman and Kimstach (1996) reported that conductivity is sensitive to variations in dissolved solids mostly mineral salts. Potable water with its own set of references and maximum values is also subject to conductivity control to ensure quality of our drinking water (Na'omi, 2005)

2.5.5 Total Dissolved Solids

These are particles that can easily be filtered through a filter paper. They may likely be in solution and may include silt and small metallic particles. Increased flow brought about by rain water tends to dilute while decreased flow concentrates the amount of dissolved solids in a running water system (Maitland, 1978). Waters with high dissolved solids generally are of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer. A limit of 500mg/L of dissolved solids is desirable for drinking water (Naomi, 2005).

2.5.6 Water Hardness

The hardness of natural waters depends mainly on the presence of dissolved calcium and magnesium salts. Hardness of water is usually expressed in milligrams of $CaCO_3$ per litre

(Lind, 1979). Soft water is usually neutral to acidic while hard water is alkaline in nature. Soft water is generally less productive than hard water (Awanda, 1987).The population density of organisms is generally higher in hard water than in soft water (Hynes, 1972). Hard water increases the rapid effects of metals on the affecting organisms, so that the destructive effect of the metal is hasten on the victims than would have been in soft water (Awanda, 1987).

Seasonal variation in water hardness often occurs, reaching the highest levels during low flow conditions and the lowest values during floods (Bartram and Balance, 1996).

2.5.7 Alkalinity

Chapman and Kimstach (1996) reported that the presence of carbonates (Co_3^{2-}) and bicarbonates ($HC0_3$) influences the hardness and alkalinity of water. In the same work, they showed that water with low alkalinity (< $24mg^{-1}$ of $CaC0_3$) have low buffering capacity and can therefore be susceptible to alteration in pH.

2.5.8 Phosphate Phosphorus ($P0_4^-P$)

Phosphate in its real form of phosphorus is a very vital inorganic substance that is present and serves in various capacities in living organisms (Awanda, 1987). Phosphate – phosphorus form is present in nucleo protein, a constituent of nucleus that promote nuclear and cell division, aids nutrition and hastens maturity and ripening of fruits (Dutta, 1974).

Phosphrous is a biologically active element hence it cycles through many states in the aquatic ecosystem and its concentration in any one state depends on the degree of metabolic synthesis or decomposition occurring in that system (Lind, 1979). Phosphate is a very important constituent of DNA; it assisted and promote energy source in living system (Awanda, 1987). Drainage from agricultural lands contributes large amount of phosphate to lakes (Mitchell, 1975). Phosphorous is not needed for growth in large quantities like carbon,

oxygen, hydrogen and nitrogen, but it is one of the more common connotation elements on land and in fresh water.

2.5.9 Nitrate – Nitrogen

Nitrate in a body of water may originates from several sources large quantity of nitrates enter rivers from municipal town sewage and a substantial amount comes from the application of inorganic fertilizers to farmlands (Awanda, 1987). Kigamba (2005) reported that the increased level of nitrates leached into African lakes comes from the excessive use of nitrogen fertilizers. Nitrates and phosphates are important for regulating biological growth in fresh water (Awanda, 1987). Decrease of nitrates in a water body results in increase in the water system. Low level nitrate concentrations may be present in natural waters (Naomi, 2005). However, a maximum level of 45mg/L is established as a world-wide guide line for nitrate concentration in water.

In Europe, the maximum allowable level of nitrate in potable water is 50mg/L, while in USA; the EPA established a guideline for the maximum level of nitrate nitrogen (NO_3^-N) of 100mg/L in drinking water supplies (Naomi, 2005).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The Reservoir is created from River Kubanniin Zaria, one of the largest cities in Kaduna State, Nigeria. It is situated in the northern guinea savannah zone. It possesses a tropical continental climate with distinct wet and dry seasons, Kubanni River is located in Zaria. The river lies approximately between latitude 11º8'N, 11º10'N and longitude 7º41'E, 7º42'E on the Zaria sheet no 102 of Nigerian ordinance survey map. The Kubanni River drains this area in a dendritic pattern, with its major drainage artery dissecting Zaria. Its water way is made up of about 157 channels which drain the entire basin as the river flows in a north, south - East direction at the gentle gradients carrying along its course superficial deposits of alluvial sands, silts, eroded detritus, younger laterite and organic matter derived from the catchment zones (Abolude, 2007).

The Kubanni River takes off from the Kampagi hills at an elevation of approximately 711meters, it thus acquires enough inertia and gravitational force for the drainage of the entire basin before empting its bed-load finally into the Galma River a major tributary of the Kaduna River (Abolude, 2007). Along its course, the Kubanni waterway meanders through deep gullies created by the weathering of granite basement rock (Ewa *et al*.,1999). Although most of the channels which vary considerably both from station to station and from time to time are seasonal flowing mostly during and shortly after the rains, the flood plains remain wet due to the shallow water table and perhaps because of the various recharge sources through the unconsolidated surface layers underlain by impervious bedrocks (Thomas, 1976).

There is therefore sufficient water for seasonal irrigation and dam embankment. Upstream, there is a dam across its valley (Kubanni Reservoir) which is used by the Ahmadu Bello

University community and partly by the people in Samaru Zaria for its water supply. Downstream, attempt to conserve river water include construction of earth or sand barrages or by artificially the enlarging and deepening pools (Adakole, 1995). There are two major uses of the river, Agriculture (irrigation, Fishing and watering cattle) and domestic (drinking, washing and bathing). Heaps of refuse dumps, human faeces, cattle dunp could be found on the slopes of the Kubanni River valley. Both municipal and industrial effluents are channelled into the river without respect to their quality.

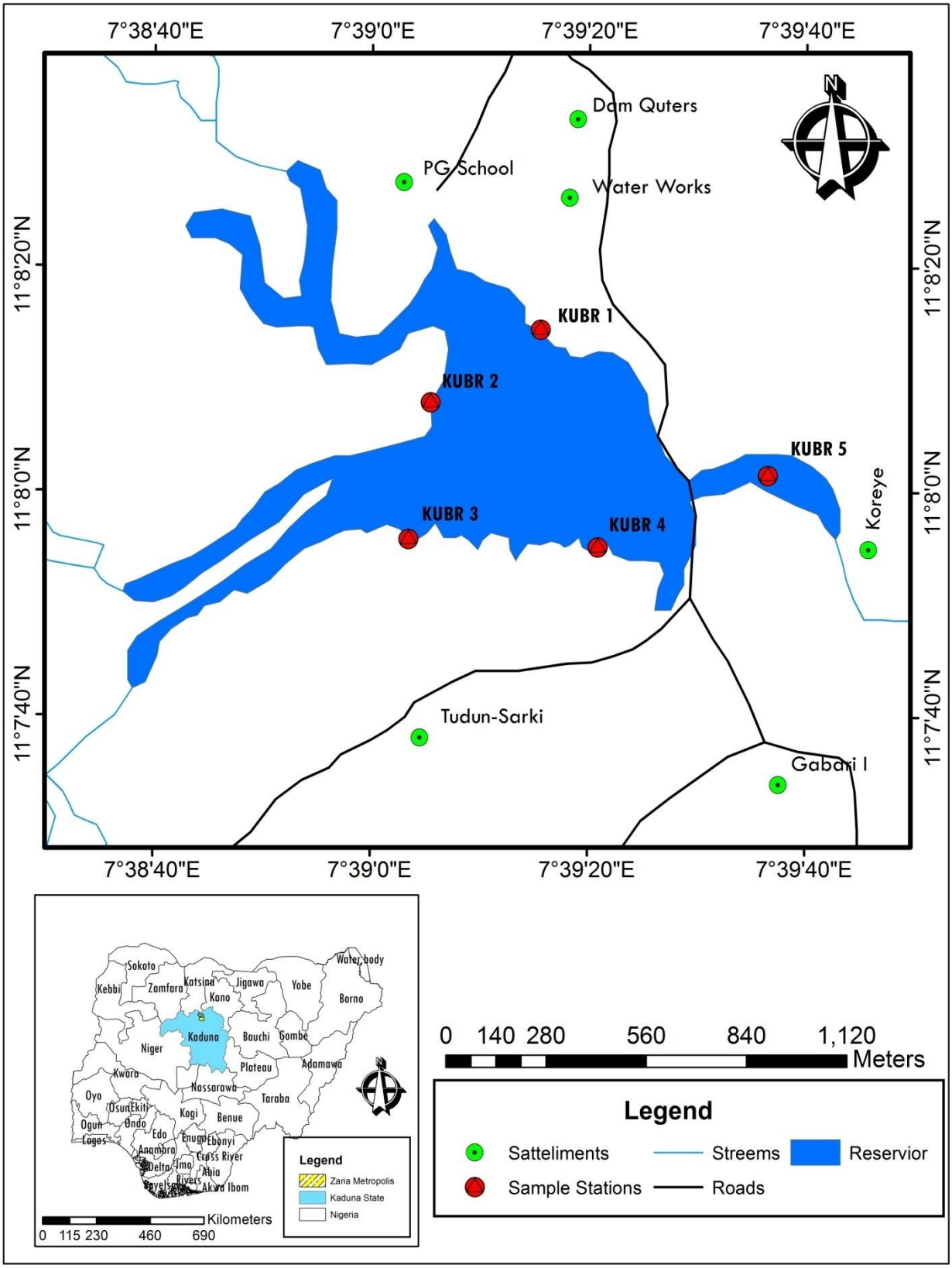

Fig 1: Map of Kubanni Reservoir showing sampling stations. Adapted from Abolude, (2007)

3.2 Selection of Sampling Stations

Five (5) established sampling stations as described by Abolude, (2007) were adopted and marked along the Kubanni Reservoir from the point Kubanni River enters into the Reservoir. The five sample stations established on Kubanni Reservoir were within an approximately 600 meters section and about 100 – 200m distance between location (Fig 1). Sampling was done between February and August 2010. These sampling stations were selected to reflect progression of pollution. The stations are as described.

Station 1: Sampling point close to the School of Post Graduate Studies, ABU, Zaria, takes care of agricultural, domestic and other wastes from the university. It is the point where Kubanni River enters the Reservoir.

Station 2: Sampling point halfway between where Kubanni River and Kudungi Stream enter the Reservoir. It takes care of agricultural, chemicals and other wastes from the adjacent farmland (Abolude,2007).

Station 3: Sampling point below where Kudungi Stream enters the adjacent farmland.

Station 4: The southern endpoint of ABU Reservoir. It takes care of the wastes from the adjacent farmland settlements.

Station 5: Site chosen along same axis occupied by Centre for Energy Research and Training (CERT). It is a point along the Kubanni River just before the entry point of sewage (from the treatment plant of the Ahmadu Bello University) into the Kubanni River (Abolude,2007).

3.3. Collection of Water samples

Water samples were collected every two weeks in a 2 litre sampling plastic bottles and taken to the Hydrobiology Laboratory, Department of Biological Sciences A.B.U. Zaria for water analyses.

3.4 Determination of Some Physico-chemical Parameters

i. Temperature: Temperature readings were taken, both air and water temperatures were measured using Hanna instrument (portable PH/EC/TDS/T^{o}) model No. H1991, 300. For water temperature, the instrument was set at zero point and then immersed in the water for about 5 minutes and the reading was taken when it stabilized. For air temperature, the instrument was set at zero point and then held in the air for about five minutes and the reading was taken when it stabilized.

ii. pH, Total dissolved solids and electrical conductivity:

For each parameter the instrument (Hanna instrument) was set at zero point and then immersed in water for about five minutes and then brought out when it stabilized,the reading was taking.

iii. Dissolved oxygen (DO)

Dissolved oxygen was determined using the azide modification of the Winkler method (Lind, 1979 and APHA 1995). Duplicate water samples in 250ml BOD stopper bottles was fixed in the laboratory immediately from the point of collection (field) with 2ml manganoussulphate, followed by 2ml alkaline-iodide azide and 2ml H_2S0_4. 100ml of the sampled water was titrated against 0.012 sodium thiosulphate until it turned to pale yellow. 1ml of the starch solution was then added and titration continued until blue colouration was observed, disappeared and it became colorless which is the end point. The reading was then taking from the calibration curve.

iv. Total hardness

This was determined by diluting 25ml water sample to 50ml with distilled water. 2ml of buffer solution and 0.lg Eriochrome black-T-dye was added. The resultant reddish solution was titrated with EDTA titrant drop by drop until a blue colour end point was observed.

Calculation:

Total Hardness was calculated as:-

Total Hardness mg/l$CaCo_3$) = A×B×1000/ml of sample

Where;

A= ml of titrant value

B= mg of $CaCO_3$ equivalent to 100ml EDTA titrant.

v. Nitrate - nitrogen

Nitrate-nitrogen (NO_3-N) was determined using phenoldisulphonic acid method as described by Mackereth (1963). 100ml of water sample was evaporated to dryness followed by the addition of 2ml phenodisulphonic acid to the residue and left for 10 minutes. 15ml of distilled water was added followed by 5ml strong ammonia solution. The resultant yellow mixture was stirred and allowed to cool. The absorbance was measured at 410nm with spectrophotometer model S 101 using distilled water as the blank. The NO_3-N concentration was read from the calibration curve gotten from the standard solution of NO_3-N.

vi. Phosphate - phosphorous (PO_4^- P)

This was determined by using Deniges method (Mackereth, 1963; Lind, 1979, APHA, 1995). 1ml of Deniges reagent and 1-2 drops of stannous chloride was added to 100ml water sample. Absorbance at 690nm was measured with a spectrophotometer, model S 101 using distilled water as the blank. The $P0_4$-P concentration of the water sample was then read from the calibration curve gotten from the standard solution of $P0_4$-P.

vii Alkalinity

100ml of well shook sample was measured and poured into a conical flask and 3 drops of methyl orange indicator were added (this gave an orange colouration). 0.02N sulphuric acid

from a burette was used to titrate the sample until the yellow colouration turned orange (indicating the endpoint).

Calculation :

Alkalinity was calculated as:

Total Alkalinity (mg/l CaCo3) = B × N × 50,000 / ml of sample

Where

B = titre value for sample,

N = Normality of acid (0.02N).

3.5 Collection of Crabs

Crab samples were collected every two weeks for six months (February-April and June-August, 2010) from the described established stations on Kubanni Reservoir using Malian traps which were set and left for 14 days. The specimens were labelled according to sampling stations and date and were placed in clean polythene bags and taken to the laboratory.

3.6 Identification of Specimens

The identification was done by using identification guide by Cumberligde (1991).

The male and female crabs were identified after Barnes (1974).

3.7 Biometric and Other Biological Data

In the laboratory, the biometric measurements taken for each specimen, were the carapace length (CL), carapace width (CW) .They were measured on a board to the nearest 0.1 centimeter from the edge of the carapace back using a vernier caliper. The weight of the crab was determined using the electronic Mettler Balance (Model P1200N).

The Fulton's Condition Factor (k) of the crab was calculated according to Bagenal (1978) with the formula; $K = 100W/ L^3$ Where k = condition factor, L = carapace length, W =weight of the crab in grams.

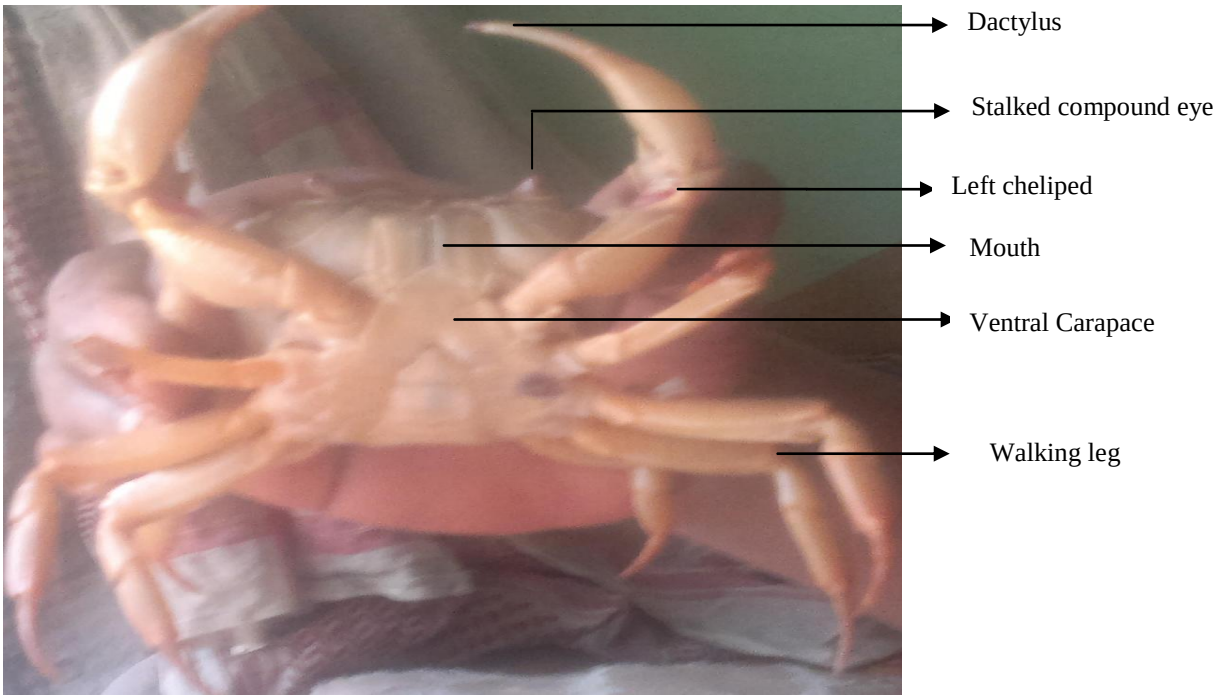

Plate i: Male *Sudanonautes kagoroensis* from Kubanni Reservoir ABU Zaria

Plate ii : Female crab with swollen abdomen containing fertilized eggs

Plate iii: Freshwater crabs *Sudanonautes kagoroensis* from Kubanni Reservoir ABU Zaria

Plate iv: Male *Sudanonautes kagoroensis* from Kubanni Reservoir ABU Zaria

Plate v: Female *Sudanonauteskagoroensis* from Kubanni Reservoir ABU Zaria

Plate vi: Malian traps set at sampling station 1 at Kubanni reservoir

3.8 Drying:

Crabs were sacrificed using chloroform and samples were dried in an oven (Gakenkamp oven, model OV-420] at 70ºc for 12 hours thereafter the dry weights were taken.

3.9 Separation of Body Components:

The crab samples were separated into four various parts, which were the claws (CL), the walking legs (WL), ventral carapace (VC) and dorsal carapace (DC).

3.9.1 Preparation of Crab Powder:

Each crab sample was ground manually to powder with an agate mortar and pestle to grain size of less than 125um forms with pre-treated mortaland pestle (Abolude *et al*, 2009). Cleaning of the mortal and pestle took place after each crushing to powder form to avoid contamination (Prendez and Carrasco, 2003). The crab powder were bagged into coded new plastic bags and sealed, for chemical analysis.

3.9.2 Chemical Analysis:

The percentage of proximate composition of crab was determined by conventional method of AOAC (2000). Triplicate determinations were carried out on each chemical analysis.

i. Estimation of moisture:

The initial weight of the sample was taken then samples were dried in an oven at about 105°C for about 8 to 10 h until constant weight was reached and the samples were minced in an electric grinder. The percentage of moisture content was determined.

$$\% \text{ Moisture content } = \frac{W2 - W3}{W2 - W1} \text{ x } 100$$

Where

W1 = weight of empty crucible

W2 = weight if crucible and sample before oven drying

W3= weight of crucible and sample after attainting constant weight on oven drying

ii. Protein determination:

The protein content of the crab was determined by micro Kjeldahl method (AOAC, 2000). It involves the conversion of organic nitrogen to ammonium sulphate by digestion of flesh with concentrated sulphuric acid in a micro kjeldahl flask. The digest was diluted, made alkaline with sodium hydroxide and distilled. The liberated ammonia was collected in a boric acid solution and total nitrogen was determined titrimetrically. The percentage of protein in the sample was calculated.

$$\text{Nitrogen percent} = \frac{(A - B)N}{W} \text{ x } 14.007 \text{ x } 100$$

Protein percent = nitrogen percent x conversion factor of protein

where;

A = Volume of titrant used to neutralize the test sample

B = Volume of titrant used to neutralize the blank

N = Normality of acid (0.02)

14.007 = The relative atomic mass of nitrogen in ammonia

W = Weight of sample in milligramme

iii. Estimation of fat:

For the estimation of fat content, the dried samples left after moisture determinations were finely grinded and the fat was extracted with chloroform and methanol mixture (AOAC, 2000). After extraction, the solvent was evaporated and the extracted materials were weighed. The percentage of the fat content was calculated.

$$\% \text{ Lipid} = \frac{W2 - W3}{W2 - W1} \text{ x } 100$$

Where W1 = weight of empty thimble

W2 = weight of thimble and sample before extraction

W3 = weight of thimble and sample after extraction

iv. Estimation of ash:

The ash content of a sample is residue left after ashing in a muffle furnace at about 550-600°C till the residue become white. The percentage of ash was calculated by subtracting the ash weight from initial weight.

$$\% \text{ Ash is then calculated as } = \frac{\text{weight of Ash}}{\text{Weight of Sample}} \text{ x } 100$$

v. Estimation of carbohydrate:

The carbohydrate was hydrolyzed with acid and the absorbance was read in spectrophotometer (LABOMED, UVD-3000) at the specific wavelength of 550 nm (AOAC, 2000).

3.10 Statistical Analysis

All data obtained were summarized and subjected to statistical analysis. Physico- chemical parameters were subjected to one way ANOVA. Moisture, ash, fat, protein and carbohydrate content of the various components were first analyzed by one way analysis of variance (ANOVA). Where a significant difference is observed, Duncan Multiple Range Test was used to separate the means. Students T test was used to test for significance between sexes with respect to season. The values $P \leq 0.05$ were considered as statistically significant.

CHAPTER FOUR

4.0 RESULTS

4.1 Physico-chemical Parameters

Table 1, shows the seasonal mean values of physico-chemical parameters of Kubanni reservoir. Air temperature was found to have a mean value of 29.57^{o}C in the dry season while in the wet season it was 28.89^{o}C. Water temperature was found to be 28.57oC and 26.78oC for dry and wet season respectively. During the dry season, electrical conductivity (164.33 us/cm) and total dissolved solid (68.83mg/l) were found to be higher than that obtained in wet season (67.20us/cm and 43.67mg/l for EC and TDS, respectively). Dissolved oxygen was found to be lower (6.4mg/l) in the dry season than in wet season (6.78mg/l). In dry season, hardness was lower (65.39mg/l) than in wet season (69.95mg/l). pH mean value (10.07) for dry season and alkalinity (59.03mg$CaCO_3$/l) were found to be higher than the values obtained for wet season (7.02 and 43.93mg$CaCO_3$/l for pH and alkalinity, respectively). Phosphate value (3.20mg/l) and nitrate values (2.63mg/l) for dry season were found to be lower than the values obtained during the wet season (3.86mg/l for phosphate and 2.74mg/l for nitrate respectively) (Table 1).

From all the parameters determined, air temperature, DO, pH, alkalinity and nitrate were not significantly different ($P>0.05$) between seasons. There was significant differences ($P<0.05$) between seasons in terms of water temperature, EC , and TDS, higher in dry season than wet season respectively while hardness and phosphate values were higher in wet season than dry season respectively (Table 1).

Table 2a-b, shows the seasonal physico-chemical values of the various stations with their means, standard errors and range.

Table 1: Seasonal Mean Values of physico-chemical parameters of Kubanni reservoir. From February to August 2010

Parameters	Dry Season			Wet Season		
	Min	Max	Mean±SE	Min	Max	Mean±SE
Air temperature (^{O}C)	26.80	32.50	29.57±0.26[a]	26.50	31.30	28.89±024[a]
Water temperature (^{O}C)	25.10	31.10	28.57±0.26[a]	24.40	29.20	26.78±0.19[b]
Dissolved O_2 (mg/l)	4.18	7.28	6.49±0.15[a]	4.96	7.42	6.78±0.11[a]
Electrical conductivity ($uscm^{-1}$)	137.00	192.00	164.33±2.75[a]	43.00	101.00	67.20±2.59[b]
Hardness ($mgCaCO_3l^{-1}$)	50.10	77.10	65.39±1.27[b]	56.90	81.10	69.95±1.15[a]
Alkalinity ($mgCaCo_3l^{-1}$)	50.00	65.00	59.03±0.75[b]	36.00	58.00	43.93±1.14[b]
pH	7.00	12.20	10.07±3.01[a]	6.10	7.90	7.03±0.07[a]
PO_4^{-p} (mgL^{-1})	1.29	4.23	3.20±0.12[b]	2.08	4.70	3.86±0.12[a]
NO_3^{-N} (mgL^{-1})	1.28	4.10	2.63±0.11[a]	1.08	4.01	2.74±0.11[a]
TDS (mgL^{-1})	49.00	78.00	68.83±1.17[a]	31.00	71.00	43.67±1.66[b]

Means with the same superscripts within the same row were not significantly different ($P > 0.05$)

Air temperature – for Air temperature, station 4 had the highest mean air temperature (30.33), while station 2 had the least. However, one way ANOVA revealed no significant difference in the mean Air temperature of all stations analysed ($P>0.05$).

Water temperature- there was observed significant difference in the water temperature of all stations involved during the study ($P<0.05$).

Dissolved Oxygen- station 3 had the lowest value while station 2 had the largest value. However, there was also no significant difference in the mean dissolved oxygen for all stations.

Electrical conductivity- there was a significant difference ($P<0.05$) in the electrical conductivity of all stations sampled, station 3 had the highest EC value (192), followed by stations 2and4 and finally station 5 had the least EC value.

Hardness - all sampled stations revealed no significant difference ($P>0.05$) in hardness.

Total alkalinity- there was no observed significant difference in the total alkalinity of all stations sampled. Stations 1, 2, 3, and 5 are significantly not different from one another, but station 4 had the lowest value of all sampled stations

There was also significant difference in TDS and Phosphate values of the sampled stations.

pH and Nitrate however showed some variations within stations but there was no significant differences in all stations.

4.2 Crab Abundance

Table 3 shows the monthly number of crabs caught per station. Station 2 and station 1 had the largest number of crabs caught for the whole study period, 60 and 55, respectively for stations 1and 2. Station 5 had the least population of crab caught (30). Also one-way ANOVA showed a significant difference ($P<0.05$) in mean number of crab species caught from all the stations (Table 3).

Table 2a: Mean Seasonal Values of physico-chemical parameters measured at the various sampling stations of Kubanni Reservoir From February to August 2010

DRY SEASON		Station 1		Station 2		Station 3		Station 4		Station 5	
Parameter		Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range
1.	Air temperature (^{O}C)	29.67±0.80	27.0-32.50	28.93±0.89	26.80-32.30	29.33±0.25	28.60-30.20	30.33±0.37	28.90-31.20	29.60±0.37	27.90-30.20
2.	Water temperature (^{O}C)	28.12±0.37	26.8-29.2	28.20±0.62	26.4-30.1	28.55±0.31	27.3-29.5	29.73±0.57	27.3-31.1	28.27.76	25.1-30.0
3.	Dissolved O_2 (mg/l)	6.81±0.20	6.08-7.28	6.89±0.16	6.29-7.25	5.93±0.45	4.18-7.25	6.49±0.035	4.98-7.12	6.32±0.39	4.86-7.02
4.	Electrical conductivity	158.0±5.79	139-172	167.0±2.89	158-175	179.33 ±6.17	153-192	167.67 ±2.25	157-173	149.67 ±5.90	137-173
5.	Hardness ($mgCaCo_3l^{-1}$)	63.45±1.72	58.0-68.10	66.07±4.35	50.10-77.10	65.88±3.06	58.20-75.70	66.53±2.40	58.10-75.60	65.02±3.01	57.20-74.20
6.	Total Alkalinity ($mgCaCo_3l^{-1}$)	61.17±1.40	57-65	58.83±1.17	55-63	61.33±1.00	57-64	54.50±1.73	50-59	59.33±1.69	54-64
7.	pH	7.74±0.20	7.20-7.90	7.76±0.14	7.30-8.10	7.93±0.10	7.60-8.30	7.50±0.30	7.00-8.50	7.65±0.17	7.10-8.10
8.	PO_4^{-p} (mgL^{-1})	3.04±0.06	2.86-3.26	3.33±0.27	2.62-4.21	3.40±0.24	2.80-4.23	3.12±0.42	1.29-4.04	3.10±0.035	2.10-4.12
9.	NO_3^{-N} (mgL^{-1})	2.73±0.15	2.30-3.20	2.92±0.32	1.88-4.10	2.39±0.29	1.28-3.07	2.58±0.19	1.92-3.10	2.54±0.20	1.95-3.10
10.	TDS (mgL^{-1})	71.33±1.12	68-75	69.33±1.36	64-73	69.50±2.26	59-74	68.33±2.84	58-76	65.67±4.47	49-78

Table 2b: Mean Seasonal Values of physico-chemical parameters of the various sampling stations of Kubanni Reservoir From February to August 2010

Wet season		Station 1		Station 2		Station 3		Station 4		Station 5	
Parameter		Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range	Mean ±SE	Range
1.	Air temperature (^{O}C)	28.43±0.56	26.90-30.60	28.52±0.73	26.50-31.20	28.87±0.55	27.20-31.00	29.42±0.42	28.20-30.90	29.23±0.50	27.90-31.10
2.	Water temperature (^{O}C)	26.67±0.62	24.4-28.6	26.88±0.57	25.0-29.2	26.72±0.50	25.3-28.9	26.65±0.19	25.9-27.3	26.98±0.23	25.9-27.4
3.	Dissolved O_2 (mg/l)	7.08±0.04	6.92-7.18	6.95±0.94	6.53-7.17	6.75±0.31	5.28-7.42	6.70±0.17	5.94-7.08	6.43±0.42	4.96-7.26
4.	Electrical conductivity ($uscm^{-1}$)	67.17±2.92	54-74	76.67±8.25	43-101	61.83±6.52	43-91	73.50±3.68	63-85	56.83±2.94	48-65
5.	Hardness ($mgCaCo_3l^{-1}$)	69.78±1.58	66.20-77.10	71.13±2.56	60.00-78.10	69.22±2.74	58.20-76.70	70.00±3.31	63.10-81.10	69.62±3.20	56.90-79.20
6.	Total Alkalinity ($mgCaCo_3l^{-1}$)	41.83±1.52	37-47	47.67±3.17	40-58	48.83±2.93	39-57	41.67±1.54	36-46	39.67±1.15	36-43
7.	pH	7.13±0.08	6.90-7.40	7.02±0.14	6.50-7.40	6.65±0.17z	6.10-7.20	6.98±0.60	6.80-7.20	7.35±0.15	6.80-7.90
8.	PO_4^{-p} (mgL^{-1})	4.22±0.11	3.98-4.70	4.19±0.09	3.94-4.50	3.77±0.20	2.98-4.23	3.12±0.39	2.08-4.30	4.02±0.16	3.23-4.32
9.	NO_3^{-N} (mgL^{-1})	2.27±0.31	1.08-3.12	2.57±0.21	1.92-3.02	2.87±0.16	2.08-3.15	3.09±0.31	2.08-4.01	2.92±0.17	2.08-3.23
10.	TDS (mgL^{-1})	44.50±2.46	37-52	52.67±5.32	36-71	42.00±2.27	36-48	41.50±3.71	31-54	37.67±1.38	34-44

Table 3: Monthly Distribution (number) of the crab *Sudanonautes kagoroensis*in Kubanni Reservoir from February- August

	Station 1	Station 2	Station 3	Station 4	Station 5
	No. of Catches				
February	08	12	05	06	02
March	11	09	02	11	06
April	05	04	06	05	03
June	13	11	05	08	07
July	10	15	09	10	05
August	08	09	13	10	07
Total	55	60	40	50	30
Mean ± SE	9.17 ± 0.72^{a}	10 ± 0.35^{a}	6.67 ± 0.01^{b}	8.33 ± 0.21^{b}	5.00 ± 0.01^{c}

Means with different superscripts within the same row were significantly Different ($P<0.05$).

4.3 Condition Factor

The monthly mean condition factor for *S. kagoroensis* is presented in table 4. There was significant difference ($P<0.05$) in the mean monthly condition factor of sampled species, with higher values in the months of July(42.59), August(41.45) and February (35.50) followed by the months of March (34.52) and April (30.48), while the month of June had the least value(25.87).

Table 5 shows the seasonal variation in the condition factor between sexes. For dry season, the males had a larger value than the females. For wet season , there was no significant difference in the condition factor between sexes. Generally, there was significant difference in the combined sexes between seasons with crabs in wet season having a lager condition factor than those of dry season combined.($P<0.05$).

Table 6 shows the monthly variation in sex ratio of *S. kagoroensis.* The male to female ratio was highest in April, June, July and August with females greater in number than males. While the months of February and March had a higher male to female ration. Generally the overall study showed more females were caught than males.

4.4 Proximate Composition

Table 7 shows the proximate composition of the various parts of the crab analysed from the various sampling stations. The average moisture content for all stations averaged between 60.40 ± 0.81% and 61.00 ± 0.32% in all parts analysed. The mean moisture value of the dorsal carapace was found to be highest of all the parts analysed (61.00 %). The claws had the least moisture content (60.40%) of all the parts analysed. However, one way ANOVA revealed no significant differences in the moisture content of the parts analysed ($P>0.05$).

For the ash content, all stations averaged between 1.04 ± 0.58 and 1.21 ± 0.08% in all the parts analysed. The ventral carapace had the highest mean value (1.21%) in this regard while the claws recorded the lowest mean value (1.04).

Table 4: Mean monthly condition factor for *S kagoroensis* from February- August

Months	Mean ± SE	Range
February	35.50 ± 1.85^{ab}	30.62-39.50
March	34.52 ± 4.26^{b}	25.32-42.72
April	30.48 ± 4.84^{bc}	21.24-40-72
June	25.87 ± 2.24^{c}	20.31-30.42
July	42.59 ± 2.17^{a}	39.56-44.62
August	41.45 ± 2.13^{a}	39.50-44.40

Means with different superscripts in the same column differed significantly ($P<0.05$)

Table 5: Mean variation condition factor (K) of *S. kagoroensis*in Kubanni Reservoir from February – August, 2010

Dry Season	Sex	
Months	Male	Female
February	37.75	33.62
March	41.72	27.32
April	38.72	22.24
Mean ± SE	39.40 ± 2.43	27.72 ± 2.22
Wet Season	Sex	
	Male	Female
June	29.42	22.31
July	43.62	41.56
August	40.50	42.40
Mean ± SE	37.85 ± 1.73	35.42 ± 1.22

Table 6: Monthly Variation in Sex ratio of *Sudanonautes kagoroensis*in Kubanni Reservoir from February- August 2010

Month	Sex	
	Female (%)	Male(%)
February	14 (42.42)	19 (57.58)
March	17 (43.59)	22 (56.41)
April	12 (52.17)	11 (47.82)
June	24 (54.54)	20 (45.45)
July	27 (55.10)	22 (44.89)
August	27(67.50)	20 (32.5)
Total	121(51.49)	114(48.51)

Average protein content from this study ranged between 12.08 ± 0.53% and 24.96 ± 0.73%. There was a significant difference ($P \leq 0.05$) in the parts analysed with the walking legs having the highest protein content (24.96%), this is then followed by the dorsal carapace (23.34%) , while the front carapace had the least protein content (12.08%).

This study showed that the carbohydrate content of all parts analysed was low (between 0.13 ± 0.18 to 0.14 ± 0.19) there was no significant difference ($P \geq 0.05$) in the carbohydrate content of all the components analysed

Finally, this study revealed a significant difference in the lipid content of the components parts analysed . The dorsal carapace had the highest percentage of lipid content (0.95%). The walking legs contained the least amount of lipid (0.5%).

Table 7: Proximate Composition of *Sudanonautes kagoroensis*in Various Stations of Kubanni reservoir from February – August 2010

Sample		Moisture (%)	Ash (%)	Protein (%)	Carbohydrate (%)	Lipid (%)
Claws						
	Station 1	62	1.2	17.2	0.12	0.68
	Station 2	59	1.05	21.2	0.16	0.76
	Station 3	61	0.98	21.5	0.12	0.74
	Station 4	62	0.86	21.7	0.20	0.77
	Station 5	58	1.12	14.1	0.12	0.98
	Mean ± SE	60.4 ± 0.81	1.04 ± 0.58	19.14 ± 1.50	0.14 ± 0.2	0.79 ± 0.5
Walking legs						
	Station 1	61	1.15	25.6	0.13	0.6
	Station 2	61	1.09	25.6	0.18	0.74
	Station 3	59	1.11	21.9	0.09	0.45
	Station 4	60	0.99	26.2	0.18	0.22
	Station 5	62	1.11	25.5	0.11	0.48
	Mean ± SE	60.60 ± 0.51	1.09 ± 0.03	24.96 ± 0.78	0.14 ± 0.2	0.50 ± 0.86
Dorsal Carapace						
	Station 1	61	1.4	11.1	0.13	0.8
	Station 2	60	1.04	11.4	0.15	0.9
	Station 3	62	1.43	12.0	0.09	1.1
	Station 4	62	1.08	11.8	0.22	0.98
	Station 5	59	1.12	14.1	0.12	0.98
	Mean ± SE	60.80 ± 0.58	1.21 ± 0.83	12.08 ± 0.52	0.14 ± 0.02	0.89 ± 0.07
Ventral Carapace						
	Station 1	60	1.71	25.9	0.13	1.22
	Station 2	61	1.03	22.1	0.09	0.93
	Station 3	62	1.03	22.3	0.20	0.77
	Station 4	61	0.98	21.5	0.13	1.02
	Station 5	61	1.23	24.9	0.17	0.81
	Mean ± SE	61.00 ± 0.32	1.20 ± 0.14	23.34 ± 0.86	0.14 ± 0.02	0.95 ± 0.08

CHAPTER FIVE

5.0 DISCUSSION

5.1 Physico-Chemical Parameters

In the study, air temperature and water temperature values were within the acceptable levels for survival, metabolism and physiology of aquatic organisms. The surface Water temperature of the tropics ranged from 25 – 32^0C. Shallow waters are about 28 – 32^0C (Abolude, 2007).The mean water temperature followed the pattern of the atmospheric temperature which is typical of the seasons in the tropical regions for all the stations observed. Abolude (2007) in his study observed similar trends. Low temperatures were observed in all the stations during the rainy season, the high temperatures observed in the month of April in all the stations are indications of the rainy period. These findings agreed with those of (Abolude, 2007, Wade 1985 and Awanda , 1987).

The pH values recorded in the study fell within the ranges reported for rivers flowing through areas with thick vegetation. The world quality standard (WHO,1996) stipulates that pH of water must be maintained between 6.5 and 9.0 pH values, above 9.0 are adverse to fish. The productivity of fish is believed to be higher in freshwater bodies with pH 6.5 to 9.0 (Fausey *et* al., 1995). The obtained pH values varied between seasons and stations, it ranged from 7.0 to 10.0 that is from slightly acidic to basic (alkaline) medium with means for the dry season and wet season (10.1 and 7.0 respectively). It shows that the water pH was slightly within the neutral zone (Abolude , 2007).

Balarabe (2001) reported that increased pH is usually correlated with photosynthetic activity. Dissolved oxygen concentrations in all the stations and seasons were generally high above 6mg/l saturation. This is similar to the findings of (Abolude, 2007). Branco

and Senna (1996) reported that oxygen saturation percentage is influenced by phytoplankton densities and organic matter decay. The high DO obtained especially during the dry season could be attributed to lower temperature and effect of mixing from top to bottom by wind action thereby increasing the dissolved oxygen. This was especially noted in station 1. This is similar to the findings of Abolude (2005). The lower concentration during the dry season could be due to the decomposition of accumulated organic matter introduced from the catchment within the reservoir which resulted in the depletion of the dissolved oxygen content. This observation agreed agreed with the findings of (Abolude, 2007 and Tukura, 2005).

Goldman and Horne (1983) observed that oxygen concentration in aquatic environment is a function of biological processes such as photosynthesis or respiration and physical processes such as water movement or temperature. Various studies suggested that maintaining minimum daily dissolved-oxygen concentrations above 3mg/l in channel cat fish and penaeid shrimp ponds assures better feed consumption and growth (Ayers,1988). Dissolved oxygen in waters depend on water temperature, partial pressure of oxygen in atmosphere and salt contents in waters (Naomi, 2005).

Alkalinity values ranged from a minimum of 43.93mg/l to a maximum of 59.03mg/l. Alkalinity of the water was found to be higher during the dry season than the rainy season, this could be as a result of the high pH values obtained during the dry season which made the water more alkaline. A minimum level of alkalinity is desirable because it is considered a buffer that prevents large variations in pH (Chapman and Kimstach, 1996). Alkalinity is not detrimental to humans.

There was no significant difference in the hardness of water from all the sampled stations between dry and rainy seasons. This is not in line with the findings of (Abolude, 2007) where he observed significant difference between station to station and from season to season. According to him the concentration was higher during the dry season than the rainy season. Kubanni Reservoir is said to be a very hard water (Abolude, 2007).

Total dissolved (TDS) varied between 43.67mg/l and 68.83mg/L (mean = 56.25 ± 1.92 mg/L). There were more suspended solids in the Reservoir during the dry season than the rainy season. The reason could be that during the dry season water volume in the reservoir become reduced as a result of evaporation. The low suspended solids in the reservoir according to Awanda (1987) and Abolude, (2007) may be due to the heavy rains that brought high floods and turbulent water currents that brought the suspended solids.

Electrical conductivity was higher in the rainy season than the dry season as a result of the dilution of the reservoir during the rainy season. This is similar to the findings of Balarabe (1989) and Abolude (2007). Gelinas *et al*., (1996) linked Nitrate – Nitrogen origin to inadequate disposal of human excreta and domestic sewage. The increase in Nitrate – Nitrogen and Phosphate Phosphorus during the wet season than the dry season can be as a result of fertilizer run-off in the water system. This is similar to the findings of (Wade,1989). Excess nitrate concentrations may indicate the presence of discharge from waste water. If allowed to continue algal blooms may occur (Oniye*et al;* 2002).

5.2 Crab Abundance

Results of the crab abundance revealed that stations 1and 2 had the highest crab abundance likely due to the high water quality as a result of self-purification due to flow,

hence favouring their survival. While the low crab abundance in station 5 may be as a result of the polluted nature of the location due to accumulation of sediments slow rate of flow, hence hindering the survival of crabs there. During the study period it was observed that there were more female crabs than males in the wet season perhaps the period corresponds with the breeding season of the females.

5.3 Condition Factor

The results of the monthly condition factor for crab studied revealed a general high condition factor of the crab, indicating that the water quality generally is favouring and adequate for their survival. The crabs are generally in a good health situation. This is similar to the result obtained by Atar and Secer (2003) using the blue crab *Callinectes sapidus* with cf values of 48.196 and 5.638. It is also in line with the works of Bello-Olusoji *et al*., 2009 using *Sudanonautes africanus* where the cf values ranged between 30.09 and 33.91.

5.4 Proximate Composition

Result of proximate composition of *S. kagoroensis*. The study reveals the percentage moisture content averaged value of between 60.40± 0.81% and 61.00± 0.32% in the parts analyzed. The obtained result is not in agreement with the average value of 67.37% reported for *Callinectes sapidus* Moronkola *et al;*(2011) as well as for sea bass and sea bream (*Sparus aurata*) and also lower than the average value 76.89% reported for *Callinectes sapidus* and 76.72 reported for sea bass which may be attributed to the influence of the season and water temperature (Nuray and Ozkan, 2007). This work is in line with the results of moisture content of European Green crab which ranged from 79.1

± 0.4% and 82.03 ± 0.5% (Naczk *et al;* 2004). Skonbergs and Perkins (2002) found 79.0 ± 0.7% moisture in *Carcinus meanus* crab. High moisture contents are considered as an advantage because of its contribution in the stabilization of the organism during movement (Eddy *et* al., 2004). According to Gokoglu and Yerlikaya (2003), Proximate ash contents of Blue Crab (*Callinectes sapidus*) and Swim Crab (*Portunus pelagicus)* caught from the Gulp of Antalya for claw meat and body meat were 1.39 ± 0.019% and 1.89 ± 0.08% respectively. This is in line with the average fat content of *S. Kagoroensis.* The ash content of species is an indication of the mineral concentration in the organism (Eddy *et al*., 2004, FAO, 2005).

The ash content of *S. Kagoroensis* averaged between 1.04 ± 0.58% and 1.21 ± 0.083 % in all the parts analysed with highest value recorded by dorsal carapace. This is also in line with the average ash content 1.040 ± 0.017 and 1.300 ± 0.001 for *Callinectes amnicola* (Moronkola *et al*., 2011).

The crab contains a good level of protein (12.08± 0.58% – 24.96± 0.78%). This in line with the average protein content 19.233 ± 0.066% and 28.00 ± 0.071% obtained in *Callinectes amnicola* (Moronkola *et al*., 2011). The average protein content is higher than the breast meat protein content of *Portunus pelagicus* (Sand crab) which ranged between 17.55 ± 0.23% and 18.83 ± 0.23% (Turelli *et* al., 2000). The high content of protein in *S. kagoroensis* further support earlier findings that crab meat can supply sufficient protein and energy in diet and that its protein is essential for growth and body defense (Gates and Parker, 1992; Hopwood, 1975). Hence, protein is essential in the diets as it is one of the basic building blocks of the body in terms of providing bones and muscles strength, endurance and immunity.

Fat content obtained in this study was found to be low in all the parts analyzed, it ranged between (0.50 ± 0.86% and 0.95 ± 0.08%), This is higher than that obtained in *Callinectes amnicola* which averaged between 0.002± 0.001% and 0.060 ± 0.050% (Moronkola *et al;* 2011). Turelli *et al;* (2000) measured Blue Crab (*Callinectes sapidus)* and Sand Crab (*Portunus pelagicus)* breast meat fat contents and found them to be 1.51 ± 0.01% and 1.532 ± 0.01% respectively, this is not in line with what is obtained in *S. kagoroensis.* However it is important to note that they essentially play a vital role in the structural and biological, function of the cells and to transport fat soluble vitamin in the body. On the other hand carbohydrate content ranged from 0.138 ± 0.18% –0.144 ± 0.18%) in all the parts analyzed, this is lower than what is obtained in *C. amnicola* which ranged between 2.013 ± 0.016% and 2.530 ± 0.022%. It was confirmed that soft shelled crab meat contained 14.31 ± 0.05% of crude protein, 1.67 ± 0.09% of ash, 84.38 ± 0.39% of moisture and 0.18 ± 0.02% of fat (% wet weight) (Benjakul and Suthipian,2009)

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

From the above study, the following conclusions can be deduced that;

i. The water quality of Kubanni reservoir favors the survival and well being of the freshwater crab (*Sodanonautes kagoroensis*).

a. The results obtained have shown that claws, walking legs, dorsal carapace and ventral carapace of *S. kagoroensis* are nutritious in terms of protein (19.14±1.50, 24.96±0.78, 23.34±0.86 and 12.08±0.52) and mineral or ash content (1.04±0.58, 1.09±0.03, 1.20±0.14 and 1.21±0.83) respectively. It can then be inferred that the crabs (*S. kagoroensis*) could be employed as a supplement of protein and mineral matter so as to balance human nutrition. Hence the consumption of crabs (*S. kagoroensis*) would help to prevent nutritional deficiencies in Nigeria and the world at large.

6.2 Recommendations

1. Crabs (*S. kagoroensis*) is a good potential source of protein for human diet and it is recommended for human utilization
2. It is recommended that farmers should put into practice the culturing of this species for commercial purpose.
3. Finally, regular survey of Kubanni Reservoir should be carried out on regular basis to monitor the quality and its productivity.

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