HABITAT UTILIZATION AND REPRODUCTIVE BIOLOGY OF NILE TILAPIA (*Oreochromis niloticus*) IN ALBERT NILE, NEBBI DISTRICT

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACK GROUND

Fishes are important renewable natural resources in Uganda that have always been exploited for both subsistence and commercial purposes from lakes, rivers, and wetlands (MAAIF, 2004). In Uganda, the Fisheries Sector provides high quality food, income and employment opportunities, supports livelihoods in fisheries dependent house holds and of recent fishing industry has become one of the most outstanding source of income both at house hold level and national level (MAAIF, 2004). The importance of fisheries as an economic activity in providing food, income and employment in Africa has been growing with increasing population and use of modern fishing gears (Balogun, 2005).

Subsistence fishing has been practiced on Albert Nile long before the 19^{th} century, however it was until the first decade of this century when commercial fish production began to develop with the introduction of synthetic gill nets and larger wooden canoes that replaced the simple gears such as basket traps, hooks, and spears as well as dugout canoes (Coenen, *et al.*, 1989).

Albert Nile supports a multi- species fishery based on endemic species which are exploited for both subsistence and commercial purposes and the fish stock assemblage includes among other fish genera of *Lates*, *Oreochromis*, *Tilapia*, *Clarias*, *Mormyrus, Hydrocynus, Alestes, Distichodus, Labe*o, *Barbus*, *Synodontis*, *Bagrus*, *Shilbe, Protopterus, and Auchenoglemis* (Maahe, 1990). To the local people and fishermen the fishery is a life line for daily incomes and food.

Nile tilapia (*O. niloticus)* is one of the fish species of great economic importance. It is a native fish species of high commercial value in Lake Albert and River Nile (Trewavas, 1983). The livelihood of the people living adjacent the river depends partly on this fishery as it contributes about 15% – 20 % of the annual total fish catch in the river. Generally, fish catches have declined and fish sizes have progressively reduced over time in Albert Nile (Department of Fisheries Resources Nebbi, 2003).

The fishery of Albert Nile is currently characterized with low and declining fish production mainly attributed to poor management of the resources. The catch rates of most of the commercial fish species has reduced over time with the increasing fishing pressure leading to over-exploitation and poor management of the resources. From personal observation, fishing is mainly concentrated in the slow flowing littoral waters of the river by majority fishermen who use various fishing methods ranging from use of gill nets of various mesh sizes, cast nets to illegal beach seines. However, littoral zones are known to be important habitats for fish breeding and nursery grounds for many species of fish (Welcomme, 1985). The use of a particular habitat by fish is influenced by spatial and temporal changes in the physicochemical factors related to feeding, resting and reproduction (Braeton & Guy, 1999) and the choice relates to how fishes are able to locate food, mates, avoid predators, reduce competition for the same resources and promote successful reproduction, growth and development (Ribbink & Lewis, 1981).

Although there is considerable information on the ecology and reproductive biology of *O. niloticus* on most of the East African lakes (Trewavas, 1983; Balirwa, 1998, Njiru, *et. al.*, 2006) little is known about Albert Nile fisheries apart from the taxonomic composition (Coenen, *et. al.,* 1989; Maahe, 1990). There is little or no study on the ecology and biology of any of the Albertine fish species hence basic knowledge on fish population distribution, abundance, size classes and condition factor as well as reproductive biology is deficient, yet such knowledge is necessary to guide proper management of the fishery. Knowledge of reproductive biology of fishes is essential for predicting population stability and fluctuations which can be used to design fisheries management measures such as closed fishing areas and seasons (Njiru, *et. al.*, 2006).

This study is aimed at contributing to that knowledge gap by providing basic information on habitat utilization (abundance and distribution, size classes, condition factor) and reproductive potential (fecundity, sex ratio, size at first maturity) of *O. niloticus* among different habitat types in Albert Nile to help guide the sustainable utilization of the fisheries resources.

1.2 PROBLEM STATEMENT

Nile Tilapia (*O. niloticus*) is one of the major commercial fish species commonly caught in the shallow inshore waters of Albert Nile. It is one of the most desirable fish species for food and commercial purposes by majority fishermen. Fish catches have over time dwindled and currently the catch per unit effort is relatively low to be of significant economic importance to the fishing communities. The fishery is currently faced with the challenge of lack of proper management practices which is partly attributed to lack of basic biological and ecological information on fish species needed to guide the proper management of the fishery. Basic knowledge on critical habitats for fish breeding, nursery grounds and fish refuge against enemies is lacking for fish species in Albert Nile which has lead to destruction of breeding sites, nursery grounds and catching of immature fish by fishers which greatly impacts on the fisheries productivity. Little or no documented information can be ascertained on the ecology and reproductive biology of any of the commercial fish species in the Albert Nile. Basic knowledge on fish species distribution, abundance, well being and reproductive potentials (fecundity, sex ratio, size at first maturity) is therefore deficient, consequently the fishery of Albert Nile is poorly understood and its future sustainability is unpredictable. This study therefore aims at contributing to the above effort by providing critical biological and ecological information needed to guide the sustainable utilization of the fisheries resources.

1.3 OVERALL OBJECTIVE OF THE STUDY

The overall objective of the study was to provide an understanding of the extent of habitat utilization and reproductive potential of *Oreochromis niloticus* among habitat types in upper portion of Albert Nile, Nebbi district.

1.4 SPECIFIC OBJECTIVES OF THE STUDY

1. To characterize the different habitat types occupied by *O. niloticus* in relation to the physicochemical characteristics.
2. To determine the extent of habitat utilization of *O. niloticus* in relation to population characteristics (size classes, distribution & abundance,) and condition factor.
3. To examine the reproductive potential based on fecundity, sex ratio and size at maturity of *O. niloticus* in Albert Nile.

1.5 HYPOTHESES

1. The different habitat types occupied by *O. niloticus* in Albert Nile have the same physicochemical characteristics.
2. The population parameters and condition factor of *O. niloticus* in different habitat types in Albert Nile are similar.
3. The reproductive potential of *O. niloticus* is the same in all habitat types.

1.6 SIGNIFICANCE OF THE STUDY

This study was aimed at providing critical baseline biological information that is required for future monitoring and guidance on the conservation and management of fisheries resources in Albert Nile. Understanding the population characteristics and reproductive biology will help fisheries managers to design strategies in establishing nursery or breeding grounds to protect the young and the brood stocks. Proper assessment of habitat and specific life history data therefore will help managers to design appropriate management measures like closed fishing areas and seasons aimed at sustainable utilization of the fisheries resources. The knowledge on the interaction between habitat and fish biology is also required for development of specific management plans for the river and other similar systems. The information generated will also provide basis for future research work.

1.7 SCOPE OF THE STUDY

The study basically focused on habitat utilization (distribution, abundance, size class and condition factor) and some aspects of the reproductive biology (fecundity, sex ratio, size at maturity) of *O. niloticus* in different habitat types in Albert Nile. The study was carried out over a period of 7 months between January and July 2007 focussing on four major habitat types namely; *V. cuspidata, E. crassipes*, *P. mauritianus* and open water zones as being predominant in the study area. Critical observations were made on the substrate types and the water flow speed besides measurements on the physicochemical characteristics of the different habitat types. Samples were collected only during the morning hours between 7.00am and 12.00 pm in all study areas.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HABITAT UTILIZATION/ SELECTION BY FISH.

A habitat is a place where a plant or an animal species naturally lives and grows or a kind of site or region with respect to physical features naturally or normally preferred by a biological species (Ribbink, 1991). An organism's habitat must contain all the physical, chemical and biological features needed for that organism to complete its life cycle (Morrow & Fishhenich, 2000). Specifically, for fishes, this may include a variety of parameters such as water temperature regimes, pH, amount and type of cover, substrate type, turbidity, depth, water velocity, inorganic nutrient levels and migration routes.

Habitats have profound effect on the life history of fish because from the habitats fish is able to locate food, mates, avoid predators, reduce competition for the same resources at the same time and promote successful reproduction, growth and development (Ribbink & Lewis, 1981). Habitat selection by fishes is not extremely rigid as most species of fish exhibit some degree of plasticity and therefore spread to various habitat types (Ribbink, 1991). *Oreochromis niloticus* has been observed and found to utilize habitats of different compositions in varying degrees (Lowe- McConnell, 1991). According to studies on habitat preference of cichlid species by Ribbink & Lewis, (1981) some species show highly specific habitat preference while others show more broad habitats. Use of habitats by some fish species is strongly influenced by spatial and temporal changes in the physicochemical factors, which are related to feeding, resting and reproduction (Braeten & Guy, 1999).

Different habitats may favour one sex and size group than the other (Balirwa, 1998). Welcomme (1985) showed that in Africa, young fishes usually colonize the littoral zone, which is the area of interface between the land and water and these are almost entirely the tilapiine cichlid species that have specific tolerance to the elevated temperature. The littoral zone offers high food supply and a favourable feeding; nursery and spawning grounds as well as fish cover against fish predatory species (Welcomme, 1985). At night when the nocturnal catfishes and other predatory fish species are active, the sight oriented diurnally active cichlids take refuge and hide motionless alongside the riverbanks, forest litters or in shallows (Lowe-McConnel, 1991).

Most tropical rivers with healthy conditions have dissolved oxygen range of 4 to 9.8mg/l, pH of 5.0 to 9.0 and temperature of 15 to 35ºC favourable for most aquatic organisms (Fryer, 1971). Dissolved oxygen is one of the important water quality parameters that determine the dynamics of the biota in natural waters because it is a regulator of metabolic processes (Beadle, 1981). In tropical water bodies vertical distribution of dissolved oxygen shows a progressive decrease from water surface to the bottom (Beadle,1981) and the surface water is kept with higher values due to oxygen diffusion at the air-water interface (Wetzel,1983).

The pH of natural waters is kept constant by the carbon dioxide, Bicarbonates and carbonate systems (Golterman, 1978) and usually decreases with increasing depth possibly due to increase in amount of decomposition (Wetzel,1983). High production of carbon dioxide in the bottom waters by the aerobic decomposition coupled with some reducing substances in the mud cause relative decrease in pH values (Wetzel, 1983).

Tilapia can however survive in a wide range of pH, temperature, dissolved oxygen, and feeds on a variety of food items in water (Balirwa, 1998; Njiru, *et. al.*,, 2006).

2.2 DISTRIBUTION AND ABUNDANCE OF FISH

Fish distribution and abundance in different habitats is associated with availability and abundance of food and substrate types in a particular habitat (Welcomme, 1985). Generally, cichlids occur in a great range of habitats from warm water open to the sun to shaded forest waters, clear nutrient poor rivers to brackish estuaries (Lowe- McConnell, 1991). Cichlid species are the most abundant fish species concentrated in the inshore fresh waters in Nigeria and their concentration in the inshore waters is an indication of ideal environment capable of providing enough food, shelter, and breeding and nursery grounds for the littoral inhabiting fish species (Balogun, 2005).

Oreochromis niloticus is one of the cichlids that occur in a wide variety of fresh water habitats like rivers, lakes, sewage channels, irrigation channels and brackish waters (Trewavas, 1983). Studies conducted in sudd areas of River Nile in Sudan by Bailey & Bailey (1987), indicated that *O. niloticus* was widely distributed in open waters, plant beds and *Eichhornia* fringed areas, but the juveniles preferred inshore areas and temporary pools on flood plains.

2.3 CONDITION FACTOR IN FISH

Condition factor is the volume of fish relative to its length and taken to mean the well-being degree of an individual fish in respect to its habitat where it lives so as to understand how well a given habitat supports life of an individual in terms of nutritional requirements and other environmental conditions (Weatherly, 1987). The condition factor is used in studies of fisheries biology to indicate the well-being degree of fish in the environment in which they live and to verify if they make good use of the foods available (Weatherly, 1987).

Different environments have influence on the well-being of fish (Medri, *et. al.*, 1990). The development of tilapia in a habitat can be determined by total biomass, increase in length and weight (Medri, *et. al*., 1990). He further postulated that the condition factor of fish in tropical fresh waters varies with seasons and breeding periods. Starvation during breeding and dry seasons causes fish to lose condition factor. Studies on Tilapia zillii in River Niger (Weatherly, 1987) showed little variation in weight over dry seasons but remarkable reduction during breeding periods. Sexual differences, age, changes in seasons, gonad maturity levels, nutritional levels and maturity of fishes can influence the condition factor (K) value (Lagler, 1952; Kotos, 1990).

2.4 SIZE AT MATURITY

Sexual maturity in tilapia is a function of age, size and environmental condition (Daget, 1956) and this has been demonstrated in Mozambican tilapia (*Oreochromis mozambicus*) which reaches sexual maturity at a smaller size and younger age than the *O. niloticus.* Fish growth in fresh water is influenced by food availability and environmental factors such as dissolved oxygen, pH and temperature (Daget, 1956). Studies on tilapia growth showed that *O. niloticus* matures at 10 to 12 months and 350 to 500 g in several East African Lakes (Popma & Masser, 1999). Tilapia population in large lakes mature at a later age and larger size than the same populations grown in controlled small farm pond environments (Popma & Masser (1999). Under good growth conditions tilapia will reach sexual maturity in farm ponds at an age of 5 to 6 months and 150 to 200 grams whereas in lakes the same species matures at about 10 to 12 months. In Tilapia species sexual maturity advances in stages and gonad maturation has been categorised into 6 stages where stage (I) comprises of immature or virgin fish, stage (II) are fish beginning maturation, (III) is a developing phase, (IV) pre-spawning stage (V) spawning stage and (VI) post spawning stage (Legendre & Duponchelle ,1996). Size at first maturity is the length at which gonad development has advanced to at least stage IV in 50% of the individuals (Njiru, *et. al.*, 2006). Trewavas (1983) found that the maturation size of *O. niloticus* was 24 cm TL in Lakes George and Victoria, 25 cm TL in Lake Edward and 28 cm TL in Lake Albert. Similarly Balirwa (1998) found that the length at first maturity of Nile tilapia in the littoral habitats of Lake Victoria was 24 cm TL for both sexes and in Lake Kyoga it was 23cm and 36 cm TL for males and females respectively.

Maturation tends to be relatively more rapid in river fish species than in lakes as river systems are in most cases unstable and fish therefore respond to unfavourable circumstances by accelerating maturation and such behaviour is typical of species of the genera *Oreochromis* (Welcomme, 1985). Tilapia living in stressful environments often exhibit earlier maturation in life and protracted reproductive periods as a means of maximizing reproductive success (Charlesworth & Leon, 1976) and such behaviours are possibly linked to a population response towards over fishing (Cowx, *et. al.,* 2003).

2.5 FECUNDITY

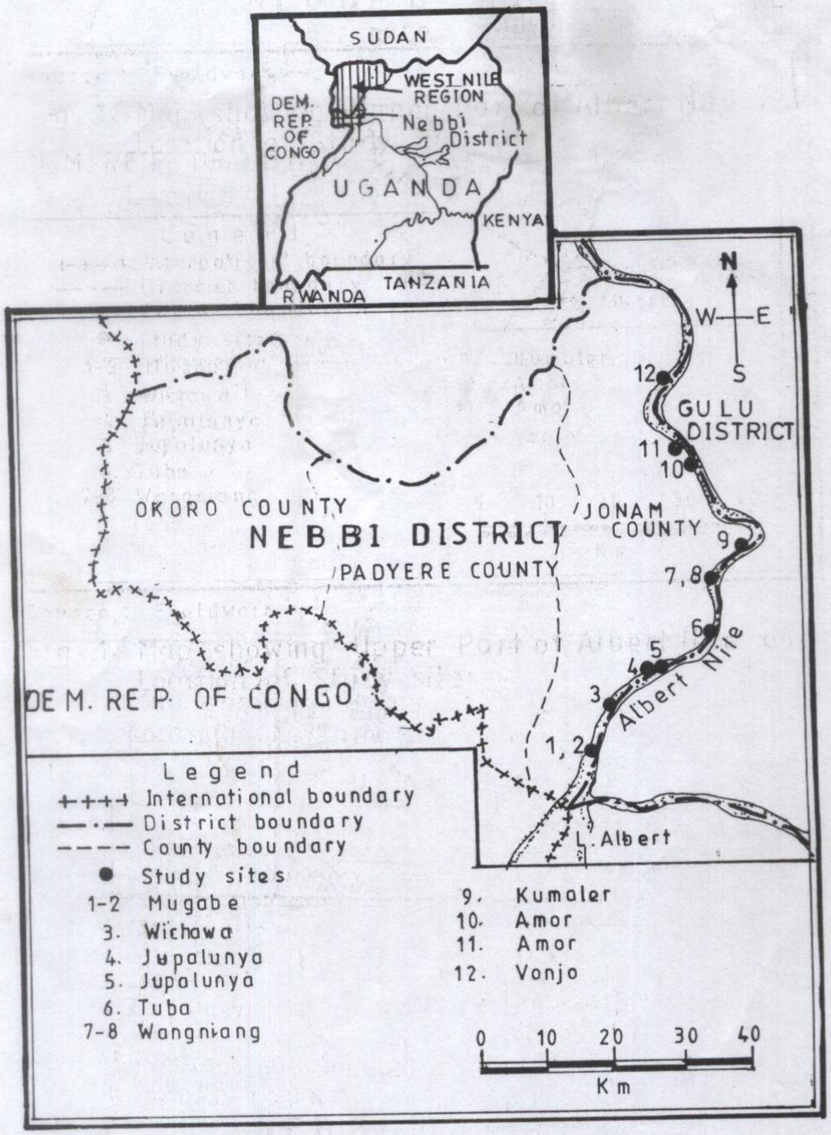
Fecundity is the mean or average number of eggs per brood and the intensity of animal reproduction is determined by both the average number of eggs per brood and how often the eggs are laid by the female per unit time (Winberg, 1971). Female *O. niloticus* produces only a few hundreds of offspring in a single spawn but under favourable conditions they spawn frequently every 4 to 6 weeks (Pullin, 1991). In mouth brooding cichlids fecundity is considerably low due to habits of parental care in which females protect the young in the mouth cavity for several weeks until they are able to survive on their own, therefore limited space available for rearing the young makes them produce small number of off springs at a time (Moyle & Cech, 2000). They further asserted that fecundity of a species varies from one system to another due to differences in food abundance and other environmental factors that affect body size of fish. Temperature and food influence the fecundity of fishes through their effect on body size as fecundity is closely related to body size of the egg-producing females (Winberg, 1971). Generally, older fish are less fecund as compared to young fish, and in the later fecundity increases progressively with body weight and growth (Njiru, *et. al.*, 2006). Most tilapia species breed continuously throughout the year with increased breeding during periods of intense sunshine or rainfall (Gomez-Marques, *et. al.*, 2003). In most cases, a major breeding peak of tilapia is associated with warm temperature, rising water levels and rainfall and high abundance of phytoplankton biomass (Babiker, 1986). *Oreochromis niloticus* releases certain numbers of mature eggs at any one spawning season and keeps the rest for subsequent season and this behaviour is usually associated with some degree of parental care (Welcomme, 1975). Parental care ensures that majority of the eggs survive to juvenile stage (Peterson, *et. al.*, 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted in the upper part of Albert Nile portion, Nebbi District covering 63 km stretch of the river from the point it exits Lake Albert. The Eastern side of the river is bordered by the Murchison Falls National Park and Game Reserve while the Western side is occupied by Jonam County (Fig.1). Most of the river channel is characterised by sandy and muddy bottoms with no open rocky areas. The shoreline vegetation of Albert Nile river is typically associated with characteristic emergent macrophytes comprising majorly of reeds (*Phragmites mauritianus),* Papyrus (*Cyperus papyrus), h*ippos grass *(Vossia cuspidata),* and several shrubs as well as floating species like water hyacinth (*Eichhornia crassipes)*. Most littoral habitats of Albert Nile have been infested with Water Hyacinth over the last 2 decades. In some spots with low water flow speed and shallow areas, water hyacinth forms permanent mats. Some permanent lagoons and depressions infringed with mixed vegetation types are also common at the mouths of small streams that enter the river channel. The flow of the river within this stretch is fairly gentle with no rapids. The relatively slow water flow through this region makes the river look more of a long complex of lake and swamp rather than a straight forward river with total fishable surface area that could exceed 400 km^2 (Coenen, *et. al.*, 1989). Meteorological information in the region (Wadelai meteorological station) indicates that the river catchments receive bimodal rainfall from March to May and July to November with heavy rain fall amounts in the latter season. During the study the area was characterised by both dry and wet season in January- March and April – July respectively.



Source : Fieldwork

Fig. 1. Map showing Upper Part of Albert Nile and Location of Study sites

3.2 DESCRIPTION OF STUDY SITES

The research work involved field study conducted in 12 selected sites in upper part of Albert Nile. The study sites were broadly categorized into three dominant shore line vegetation types and open water zones. For each habitat type, 3 replicate sites were randomly selected at different locations from which samples were drawn. The habitats types included *Phragmites (*4, 5 & 1) found at Jupalunya, Tuba and Amor Ferry fishing grounds; *Vossia cuspidata (6, 10 &12)* located at Wangniang, Amor Ferry and Monvonjo fishing grounds; *Eichhornia crassipes (*2, 3 & 9*)* located at Mbagoro/ Mugobe, Wichawa and Kumaler/ Pajobi fishing grounds and open water zones about 100 meters from the shore line (1, 4 & 8) were found at Mbagoro/ mugobe, Jupalunya and Wangniang. The sampling sites were of varying distances from the other (Fig.1).

3.3 FIELD DATA COLLECTION

3.3.1 Physicochemical parameters.

Data on some selected physical and chemical water quality parameters were collected in upper part of Albert Nile at monthly intervals from January to July 2007. The water quality investigations specifically focused on water temperature, dissolved oxygen, water depths, transparency, pH, and conductivities to understand if they have influence on habitat utilization and reproductive biology of *O. niloticus.* In order to detect changes in the water transparency, water temperatures and dissolved oxygen, measurements were taken during morning hours between 7.00 am and 12.00 pm throughout the study period to avoid temporal variations during the day. For each of the study sites objective observations were made on other physical factors such as water flow speed and bottom substrates.

i) Water depths were measured by lowering a weighted rope until it touched the bottom floor of the river. The length of the rope immersed in the water was measured using a meter rule and this was repeated at 3 different spots within the study site so as to get an appropriate average depth.

ii) Transparency was measured with a Secchi disc of 20cm diameter. The depth of transparency was calculated as the mean distance where the disc disappears when viewed from the surface of water and the point when it reappears upon rising after it has been lowered beyond visibility.

iii) Water temperature in each study site was read and recorded directly from Oxygen meters. Measurements were taken both at the surface waters (about 20 cm) and at the bottom of the water on each sampling day in the morning hours at 7.00 am and 12.00 pm when nets were set and hauled respectively.

iv) Dissolved oxygen was measured by oxygen meter by dipping its probe into the water 20 cm from the water surface and at the bottom water in each site.

v) pH was recorded using a portable pH meter model 43800-00 by Hach Co which was standardised every month and the pH was determined by dipping its probe into the water both at the surface (20 cm from water surface) and at bottom of water in all study sites.

Vi) Conductivity was determined by measuring the resistance occurring in the area of water using the conductivity meter of model 44600 by taking measurements similarly at the surface and near bottom of water

3.3.2 Fish Sample Collection

Fish samples were colleted monthly between January and July 2007 using two fleets of multi mesh gill nets a small seine net operated from a boat. Two fleets of multi mesh multifilament gill nets consisting of different panels joined end to end and comprising of stretched mesh size range from 37.5 mm to 125.0 mm were used. The two fleets were set parallel to the shoreline about 1m and 40m respectively at 7.am and retrieved at 12.00 pm on each sampling day. At the time of retrieving the nets, the area between the two nets was first boat seined once with a seine net of about 40 meter length, 2 meters deep and mesh size 1.50 cm on each to capture any fish that was not caught by the experimental gill nets in the sampling area. The seine net was deployed from a boat in a semi circular manner confined to the area between the two set gill nets. Immediately after fish were retrieved from the nets other species were discarded off while *O. niloticus* were retained. The total lengths (TL) and body weight (WT) were measured for each individual *O. niloticus* to the nearest 0.1 cm and 0.1 gram respectively.

3.3.3 Determination of Stomach fullness

The stomachs were removed and observed for stomach fullness and ranked based on Daget (1996) ranking scale of 0% 25%, 50%, 75%, and 100% to assess the feeding regime and relative food abundance in the habitats. The degree of stomach fullness 0% represents empty stomach (E), 25% represents food occupying a quarter of the stomach (Q), 50% is food occupying a half of the stomach (H), 75% representing three quarter full stomach (TQ) and 100% represents stomach completely full (C). The number of fish categorized under each stomach fullness category was counted and recorded.

3.3.4 Sex determination

Individual fish samples were dissected to determine sex and gonad maturity status by examination of gonads. Maturity status of each fish was determined and assigned as stages I, II, III, IV, V and VI following Legendre and Dupenchelle (1996) procedures where stage I comprised of immature or virgin fish. Both sexes had non active gonads and under a magnifying lens looked very small, thin or thread like occupying a small part of the body cavity; Stage II was the early maturing phase/ fish beginning maturation; Stage III was the developing stage where in females, minute eggs whitish in colour appeared in an expanded ovary that occupies about two thirds of the abdominal cavity and in males the testes were enlarged and increased in volume, flat in appearance; Stage IV was the pre spawning stage where ripen eggs yellowing in colour appeared in female ovaries occupying almost entire body cavity and in males, the testes became more whitish in appearance; Stage V was the spawning stage where gametes were seen flowing. In females the transparently yellow ripened eggs loosened from the ovary wall were visible through the ovarian wall and some were seen flowing with slight pressure on the abdomen. In males the testes looked thicker and expanded and milt was seen flowing out with slight pressure on the abdomen; Stage VI was of post spawning individuals whose gonads were spent already. In both cases gonads looked shrunken. Ovaries were flaccid sac like and reduced in volume but contained some of the un- spawned eggs and a large number of un- ripened small ova.

3.4 DATA ANALYSIS

3.4.1 Physicochemical parameters

The data collected on the selected physical and chemical water quality parameters was subjected to descriptive statistics and analysed using Analysis of Variance (ANOVA) to test for significant differences of the parameters among habitats types.

3.4.2 Fish Abundance

Abundance was considered as the number of individuals captured in a given habitat in a specified period. The total number of *O. niloticus* captured monthly per habitat type during the sampling period (total number of fish captured by the gill nets and seine net combined) determined the abundance in a particular habitat type. Abundance by biomass was also considered by habitat type. The number of fish and total weights per habitat types were both presented graphically. Pearson's product moment correlation was applied to determine whether fish abundance correlated with water quality parameters.

3.4.3 Population structure by length groups

The individual total lengths recorded were used to determine the size classes. Population structure by length group of *O. niloticus* captured in each habitat type was presented using length frequency histogram (length frequency plotted against the actual lengths to obtain frequency). Separate histograms were made for the length groups in each habitat type.

3.4.4 Condition factor

The Fulton condition factor was used to determine the condition of fish in their respective habitats. The individual total lengths and total weights recorded were used to determine the condition factor of *O. niloticus*. Condition factor (K) was calculated from the formula $K = W/L^3 X 100$, where W = wet weight of an individual fish specimen, L = total length of an individual fish and 100 is a constant. Because of higher variances in the weight of smaller young fishes, analysis of condition factor was done of fishes of size range 12 to 42 cm total lengths. Fish were grouped into two size groups as fish < 20 cm TL and fish > 20 cm TL and condition factor determined for each group. Adjusted mean for the K values for the different size classes was then considered for evaluation of the well- being of fish. Overall mean K was also determined for the sampled population from each habitat type to understand which habitats provided better growth supports to the fish.

3.4.5 Size at first maturity

Fish were grouped as juveniles (stages I, II, III) and adults (Stages IV, V, VI). The size at first maturity was estimated as the total length class at which 50% of all the individuals were sexually mature following Njiru, *et. al.*, (2006) procedures. The fish in maturity stage I, II, III, were therefore considered immature and those in stages IV and V considered mature for purpose of calculating size at 1^{st} maturity (Njiru, *et. al.,* 2006). The size at first maturity was determined by grouping the ripe stage IV and V males and females separately into 2cm length class interval. The resulting cumulative frequency was subjected to logistic curve function (the S-shape curve) and the length where 50% of the individuals fall was determined for both males and females. The monthly frequency of the various gonad stages was plotted by month to determine breeding periods.

3.4.6 Sex ratio

The actual number of fish whose sexes were successfully determined were considered for sex ratio and the sex ratio expressed as the ratio of number of males to females was analyzed by habitat type. The significant deviations from the hypothetical 1:1 ratio were determined using Chi square test at $P< 0.05$ significance level.

3.4.7 Fecundity

The actual number of mature eggs in the ovaries was physically counted to determine the fecundity of *O. niloticus.* Fecundity was estimated from total counts of eggs in the ovaries of fish in the most advanced state of development (Njiru, *et al.,* 2006). Ripe females of stage IV and V were used for the fecundity estimation. A mean fecundity for all the samples was then determined. The relationship of fecundity with total length (TL) and the body weight (Wt) of fish was analyzed by regression analysis procedures and expressed by the following equation, $F = m\ TL^{n}$ and $F = a\ W^{b}$, where F = fecundity, TL = total length of individual fish, W = body weight of individual fish, m , n, a, and b are constants.

CHAPTER FOUR

4.0 RESULTS

4.1 Physicochemical parameters of habitat types

The analysis of data on the physicochemical characteristics of the habitat types studied in upper part of Albert Nile indicated that the water temperatures varied from 26.1 ^{o}C to 32^{o}C among the different habitat types with the overall mean value at 28 ± 1.6 ^{o}C. The highest recorded value of 32^{o}C and mean 29 ± 1.6 ^{o}C was in surface waters of *E. crassipes* and the lowest values of 26.1 ^{o}C was in the surface waters of *V. cuspidata* habitat. The variation of water temperatures among habitat types was not significant ($F = 1.6489$; $p < 0.05$). Dissolved oxygen levels varied from 4.2 to 10.1mg/l among the different habitat types and the variation was significant ($F = 12.1062$; $p < 0.05$). The highest average 7 ± 1.4 mg/l was in the surface waters of open waters while the lowest surface oxygen levels 5 ± 1.3 mg/l was found in *E. crassipes*, covered areas (Table 4.1). The highest recorded value 10.1mg/l was in the surface waters of open water areas while the lowest value 4.2 mg/l was found in *E. crassipes* habitat (appendix 8). Generally, dissolved oxygen concentrations were higher in the open waters than in vegetation covered water and vertically the oxygen concentrations decreased with increasing depth in all the study sites (appendix 8). The overall average of dissolved oxygen in the study area was 6 ± 1.3 mg/l for surface waters and 5 ± 3.2 mg/l for bottom waters.

The water depths varied from 0.95m to 1.63m among habitat types and the differences were significant ($F = 5.8120$; $P < 0.05$). However, the water levels slightly increased in response to the heavy rain falls between May and July. Transparency was relatively higher in open water zones and lower in vegetated water areas (Table 4.1) which implied that vegetated water areas were generally more turbid or cloudy than the open waters which was relatively more transparent. Conductivity and pH did not vary significantly in all the habitat types and the pH decreased with increasing depth in all the habitats (appendix 9). The mean pH value for all the habitat types was 7 ± 0.4 while conductivity was 233 ± 36.8 (Table 4.1).

Table 4.1:The Range and Mean of physicochemical parameters of water in different habitats types in Albert Nile (January- July, 2007)

Parameter	*V. cuspidata*		*E. crassipes*		*P. mauritianus*		Open water	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Water depth (cm)	128 -148	138 ± 6.3	95 -108	100 ± 5.2	113 -121	115 ± 3	136 -163	149 ± 9
Transparency (cm)	41- 59	52 ± 6.46	48 - 55	52 ± 2.0	41- 60	51± 4.8	47- 58	54 ± 3.5
Temperature (°C)	26.1-30.9	28 ±1.65	26.8 - 32	29 ± 1.6	26.4 - 30.0	28 ± 1.5	27.0- 31	28 ±1.6
D/ Oxygen (mg/l)	4.9 - 9.1	6 ± 1.32	4.2 - 8.3	5 ± 1.3	5.2 - 8.9	6 ±1.2	5.9 -10.1	7±1.4
pH	6.6 -7.7	7± 0.45	6.8 - 7.8	7± 0.32	6.7- 7.7	7± 0.4	6.7- 7.9	7± 0.5
Conductivity (µsm)	194- 253	225 ± 31	208 - 249	228 ± 28	154 -290	220 ± 52	219 -310	259 ±36

Table 4.2: Characteristics of habitat sediments (substrate types) and water flow speed of habitat types in Albert Nile (January- July, 2007)

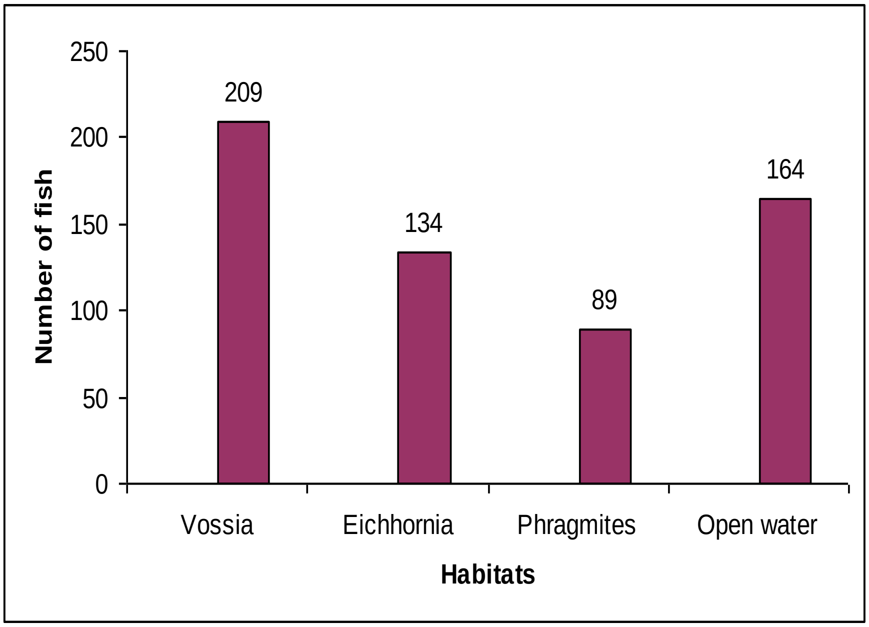
Habitat type	Sediment/Substrate type	Water flow speed
Vossia cuspidata	Sand or mud/ debris and, snail *shells*	Slow flowing water
Eichhornia crassipes	*M*ixture of sand/ silt, debris	Slow flowing water
P. *mauritianus*	Muddy, debris & Snail shells	Fast flowing waters
Open water	Mixture of sand/ silt	Mild flowing water

Generally the bottom sediment or substrate of the river varied from sandy or muddy substrates intermingled with snail shells or debris and in other areas to a mixture of sand, silt and snail shells across the different habitat types. *Vossi*a *cuspidata* which forms extensive submerged vegetation cover in-stream, had sediment type mainly consisting of sand and debris (decomposing plant material) and snail shells. The water flow was relatively slow or mild. Under *E. crassipes* which formed large floating mats on water the areas were characterized by calm water and water depths of less than 1 metre. The sediments in these areas consisted of a mixture of debris and sand with snail shells in some areas. The *E. crassipes* habitats exhibited the lowest dissolved oxygen and highest mean water temperatures among habitat types. In *P. mauritianus* habitat where the vegetation cover was less extensive in-stream but more of ectone cover, some areas had muddy sediments while others had sand mixed with snail shells and the areas were further characterized by fast running water among other study sites. In open water zones which were 100 metres from the shore lines, the sediment consisted of a mixture of sand, silt with decomposing matter and snail shells.

4.2 Abundance and distribution of fish among habitat types

A total of 596 fish samples were collected from the four habitat types between January and July 2007. *Oreochromis niloticus* was found distributed in all the habitat types but representation by numbers in various habitat types differed significantly ($F = 6.5634$, $P < 0.05$) with highest abundance recorded in *V. cuspidata* (35.7%), and open water (27.5%) respectively while *P. mauritianus* habitat showed the lowest abundance (14.9%). The total biomass was highest in open water followed by *V. cuspidata* with least recorded in *P. mauritianus* (Fig 4.1).

(a) Numbers



(b)Weight

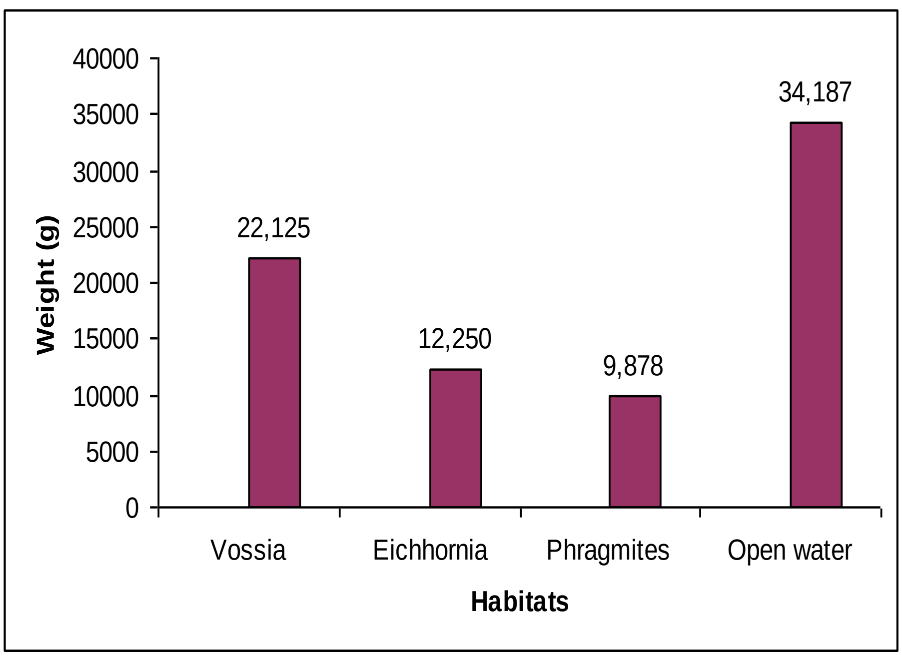


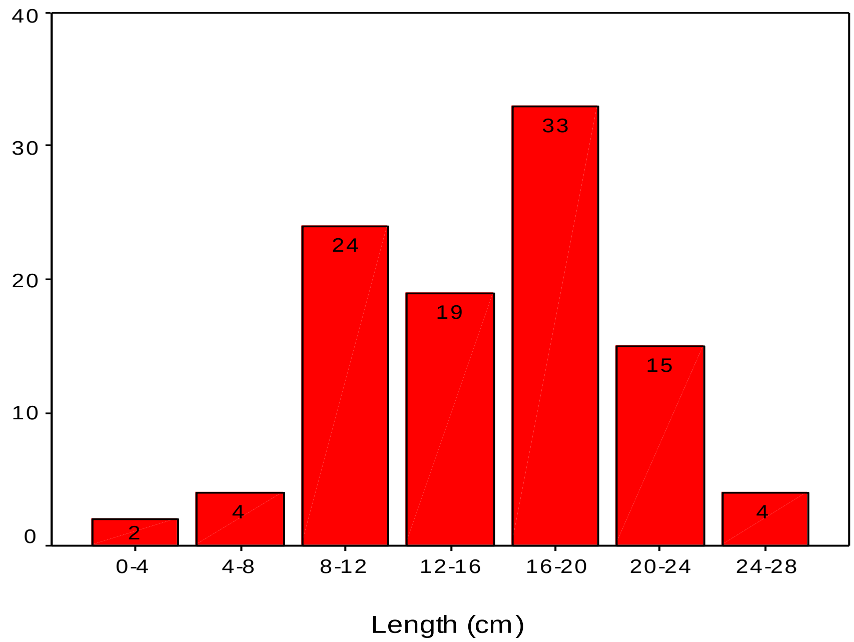
Fig.4.1: The relative abundance of *Oreochromis niloticus* by (a) numbers (b) weight in different habitats in Albert Nile (January – July, 2007).

The monthly fish catch for the period January to July 2007 indicated strong variations of catches by habitat type and the contributions of catches in February and April were significant (appendix 7). Abundance of fish in various habitat types correlated substantially with water depths ($r = 0.6$; $p < 0.05$) while temperature, transparency and dissolved oxygen correlated moderately but pH and conductivities showed negligible correlation (Table 4.3).

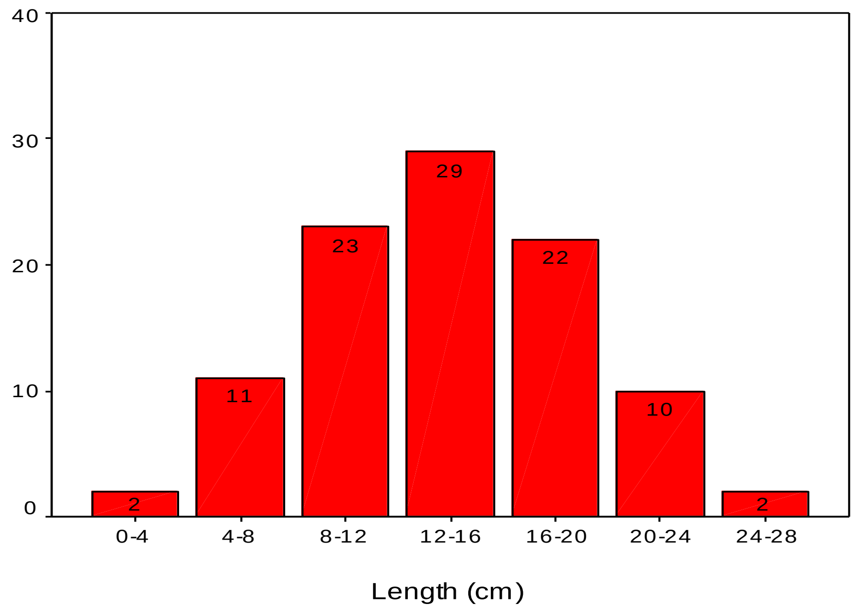
4.3 Population structure by size groups/classes

The size of *O. niloticus* population from all the sampled habitat types in Albert Nile ranged from 2.3 to 42 cm total length (TL) and the overall average size was 16.8 ± 0.45 cm TL. Multiple size classes of juveniles and adults were captured monthly throughout the sampling period (appendix13)**.** The highest size class in *V. cuspidata* was 16-20, followed by 8-12 cm TL while in *E. crassipes* the highest was 12 -16 cm TL, followed by 8-12 cm TL whereas in *P. mauritianus* and open water the highest size classes were 8 – 12 cm and 20- 24, respectively (Fig 4.2). Generally, in *V. cuspidata*, *E. crassipes* and *P. mauritianus* habitats most fish were in the size range 8 to 24 cm TL while in open water habitat the greatest proportion were in size range 24 to 28 cm TL (Fig.4.2). The greatest percentage of immature fish or juveniles of sizes ≤ 20 cm TL were found in *V. cuspidata* (38.9%) followed by *E. crassipes* (26.7%) habitats. Overall the greatest proportion of *O. niloticus* population in all habitat types was fish of size range 8 to 24 cm TL with sizes ≤ 22 cm TL more abundant in vegetated shore waters (67.3%) and sizes ≥ 22 cm TL were more commonly found in open water zone (Fig.4.2). There was no significant seasonal variation in abundance of size groups in all the habitat types (appendix 12 &13).

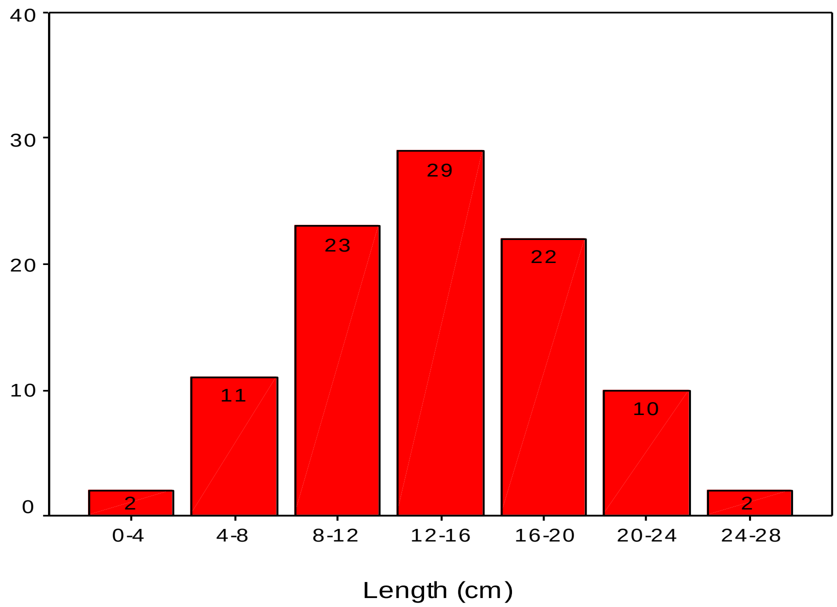
(a) *V. cuspidata*



(b) *E. crassipes*



(c) *P. mauritianus*



(d) Open water

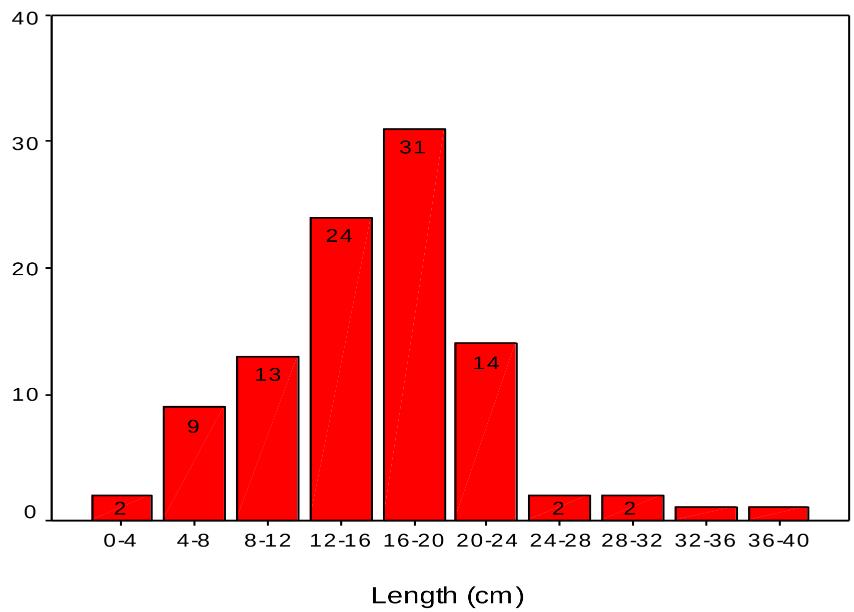


Fig 4.2: Length frequency distribution of *O. niloticus* in *(a) V. cuspidata*, (b) *E. crassiipes*, (c) *P. mauritianus* and (d) open water habitat in Albert Nile (January – July, 2007).

4.4 Stomach fullness in different habitat types

A total of 542 fish samples examined for stomach fullness in all the habitat types indicated that overall, the largest proportion of individuals was fish of 50% stomach fullness, followed by 25% stomach fullness (Table 4.3). The greatest proportion of fish whose stomach fullness exceeded 0% fullness were found in open waters and *V. cuspidata* habitats compared to *P. mauritianus* and *E. crassipes* habitats indicating that there were variation in food availability or fish have better ability to feed in open waters and *V. cuspidata* dominated shore areas during the sampling period.

Table 4.3: Distribution of stomach fullness in habitat types in Albert Nile (January – July, 2007).

Stomach fullness	E	Q	H	TQ	C	Total
Vossia	18	42	54	30	11	155
Eichhornia	30	53	27	17	7	134
Phragmites	19	20	38	10	2	89
Open water	20	43	56	30	15	164
Total	87	158	175	87	35	542

4.5 Condition factor (K)

Condition factor is the volume of fish relative to its length and taken to mean the well-being of individual fishes in respect to their habitat where they live and to understand how well a given habitat supports life of an individual in terms of nutritional requirements and other environmental conditions. The condition factor K of the pooled population of *O. niloticus* ranged from 1.56 to 2.44 and the average was 2.05. The condition factor for males and females ranged from 1.70 to 2.48 and 1.56 to 2.31 respectively (Table 4.4 & 4.5). The open water habitat population had the highest mean K value, followed by *P. mauritianus* while the least K value was observed in *V. cuspidata* habitat (Table 4.4 & 4.5). Analysis of variance showed that the differences in the condition factor among habitat types was significant (F= 4.5123, P< 0.05). Generally, the observed K was higher in males compared to females in the same age groups and habitat type and there were some slight increases of K in the months of January, April, and May.

Table 4.4: The monthly mean condition factor for males in different habitat types of Albert Nile (January-July, 2007)

Month	*Vossia*	*Eichhornia*	*Phragmites*	Open water
J	2.36	2.19	2.20	2.26
F	1.70	1.89	1.89	2.48
M	2.05	2.35	2.45	2.28
A	1.87	2.15	2.29	1.99
M	1.97	1.94	1.84	1.96
J	2.04	1.95	1.88	1.98
J	2.07	2.10	2.34	2.39
Grand Means	2.01	2.08	2.14	2.19

Table 4.5: The monthly mean condition factor for females in different habitat types of Albert Nile (January –July, 2007)

Month	*Vossia*	*Eichhornia*	*Phragmites*	Open water
J	2.01	2.27	1.83	2.08
F	1.88	1.86	1.95	2.09
M	1.97	2.05	2.09	2.06
A	1.72	1.92	1.56	1.85
M	1.96	1.96	2.31	1.87
J	1.95	1.93	2.22	2.05
J	1.90	1.99	2.11	2.04
Grand Means	1.92	2.00	2.02	2.06

4.6 Sex ratio

A total of 469 fish samples were examined for sex determination and the sizes ranged from 9.4 to 42 cm in total length and 28 to 1700g in body weight with 265 females (57.7%) and 204 males (42.3%). The overall sex ratio (Males: Females) was 1: 1.3 which was slightly different from the normal hypothetical sex ratio 1:1 ($\chi^2 = 7.42$, $p < 0.05$). The total number of females was significantly greater than males in *V. cuspidata* ($\chi^2 = 4.36$, $p < 0.05$) and *E. crassipes* ($\chi^2 = 3.18$, $p < 0.05$) but in *P. mauritianus* and open water the ratios were insignificant (Table 4.6). Females were generally more numerous in all habitat types.

Table4.6: Sex ratio (Males: Females) of *O. niloticus* in different habitat types in Albert Nile (January- July, 2007)

Habitat	Total	No. females	No. males	Sex ratio	χ^2	P < 0.05	
Vossia	156	91	65	1: 1.40	4.36	0.05	S
Eichhornia	102	60	42	1: 1.43	3.18	0.05	S
Phragmites	61	32	69	1: 1.10	0.16	0.05	NS
Open water	150	81	69	1: 1.17	0.96	0.05	NS
Totals	**469**	**264**	**205**	**1: 1.29**	**7.42**	**0.05**	**S**

S – Significant NS – Not Significant

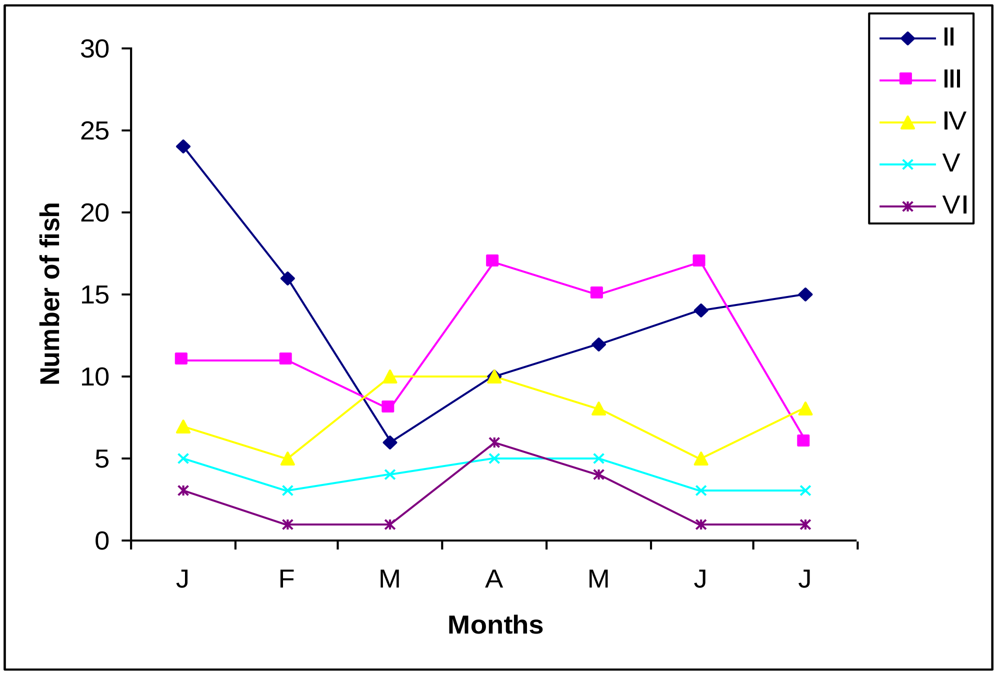
4.7 Sexual maturity stages

The relationship between body length and gonad development stages was examined in 469 fish samples. It was noted that young males and females attain maturity at different body lengths. The monthly percentage of each gonad development stages in males and females is illustrated (Fig.4.3). There was high frequency of occurrence of all the stages of gonad development and maturation in *O. niloticus* and multiple sizes of juveniles and mature fish were monthly collected throughout the period.

According to the female gonadic maturation stages, 35.80% of the total females were in the maturing stage II, 27.67% were in mature stage III, 19.92% were in the ripe stage IV, and 10.71% were in the ripe and flowing stage V while 5.16% of the fish were in spent stage VI. Therefore, 35.79% of the total females were in the reproductive process (Fig. 4.3). In females, a greater proportion of gonadal ripe stages IV and V were observed in the months of April and May, similarly fish in spent stage VI (Fig 4.3).

In males, 17.69% of the fish were in maturing stage II, 40.41% were developing stage III, 24.25% were in ripe pre spawning stage IV, 9.10% were ripe and flowing stage (spawning) V and 8.59% were the spent VI. Therefore 41.94% of the male fish were in the reproductive process (Fig.4.3). Gonadal ripe stages IV and V were more observed in the months of January, April and May and similar patterns were observed for fish in spent stage VI and the spawning fish were more commonly observed in *V. cuspidata* and *E. crassipes* habitats but a greater proportion of egg bearing females were caught in the open water areas (appendix 17).

(a) Females



(b) Males

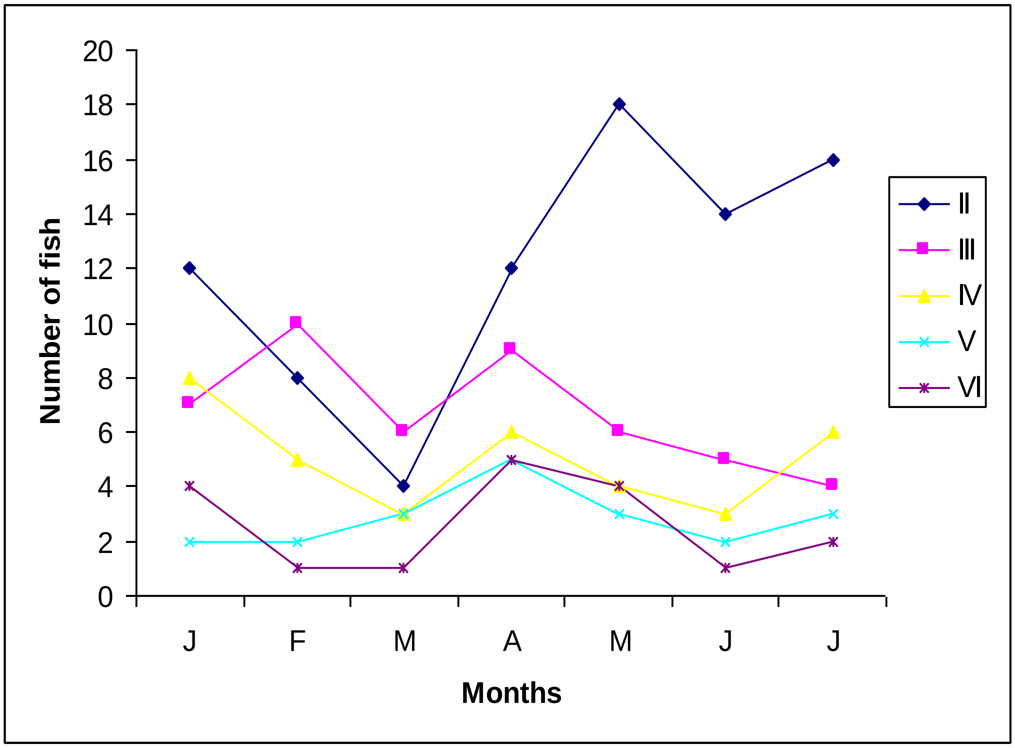


Fig. 4.3: Monthly frequency of gonad maturity stages in (a) Females (b) Males in Albert Nile (January- July, 2007)

4.8 Size at first maturity

The smallest ripe female *O. niloticus* of stage (IV) was 17.6 cm total length and 108g body weight while the smallest ripe male was 17.8 cm total length and 200g body weight. The size at first maturity where 50% of the individuals had attained gonad development stage IV was 22.4 cm and 23.0 cm TL for females and males respectively (Fig 4.4). It was notable that females and males mature at different lengths but females mature slightly earlier than males.

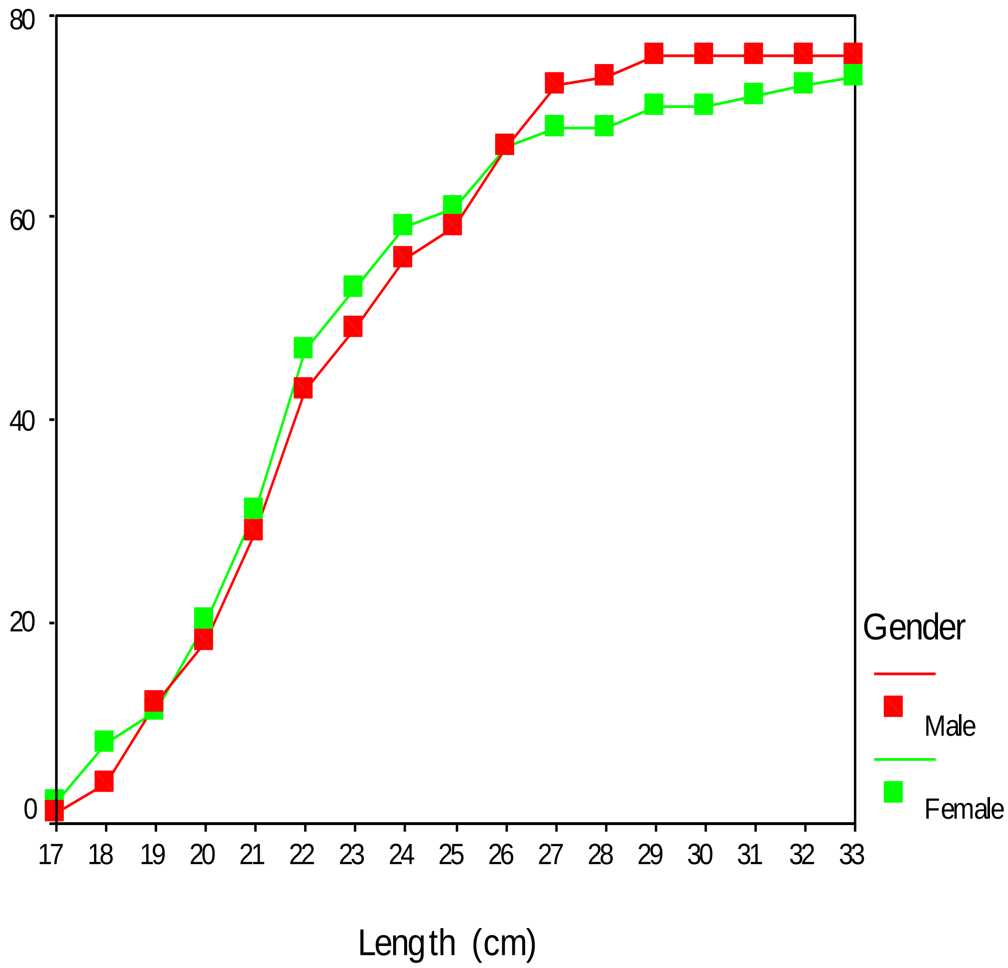


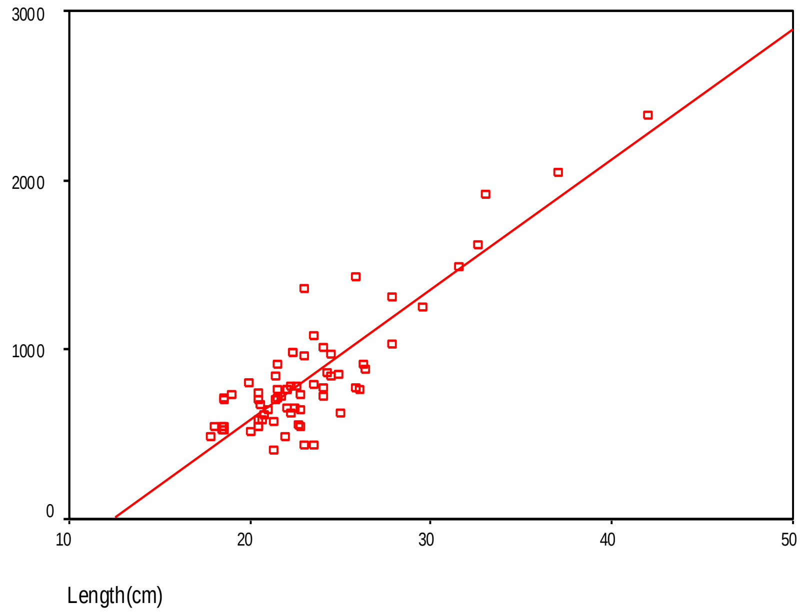
Fig. 4.4: Diagram showing cumulative frequency curve (Ogive) of lengths for stage IV & V in males and females

4. 9. Fecundity

The size and weight of ripe females examined for fecundity estimation ranged from 17.6 cm to 42 cm TL and total weight ranged from 108g to 1700g respectively. The number of eggs for all the broods examined ranged from 412 to 2380 oocytes. The overall mean fecundity obtained by direct summation procedure for the fish population was 854 oocytes per fish.

The relationship of fecundity with fish total length and body weight were found to be linear and increasing with increasing fish length and body weight (Fig 4.5). Fecundity correlated more with the body length than body weight (appendices 18 & 19). Fecundity increases with body length, a relationship described by the equation $F = 7.98\ L^{1.456}$ where F = fecundity, TL = total length of individual fish (cm) and the correlation was very significant ($r= 0.88$, $p < 0.01$).The relationship of fecundity with body weight was expressed by the equation; $F = 38.3\ W^{0.564}$ where F= fecundity, WT= total body weight (Fig. 4.5) and the correlation too was significant (appendix 18 & 19). Among environmental variables fecundity correlated highly with temperature regimes of water and dissolved oxygen (appendix 18).

(a) Body length; $F = 7.98\ L^{1.456}$



(b) Body weight; $F = 38.3\ W^{0.564}$

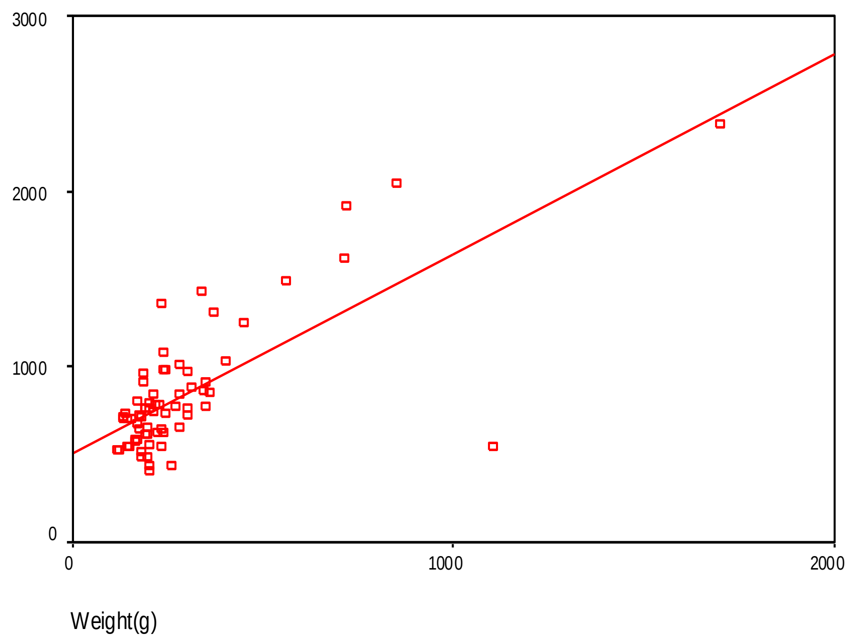


Fig 4.5: The relationship of fecundity and (a) Body Length
(b) Body weight of *O. niloticus* in Albert Nile
(January – July, 2007).

CHAPTER FIVE

5.0 DISCUSSIONS AND CONCLUSION

5.1 DISCUSSION

5.1.1 Physicochemical parameters

The current study examined the association between some physicochemical water quality parameters, and some aspects of reproductive biology and ecology of *O. niloticus* in Albertine river system. One of the important water quality parameters investigated was dissolved oxygen levels among habitat types in Albert Nile which was found to be higher in open waters than vegetated habitats. This finding probably indicated that vegetation cover on a water surface has an effect of reducing dissolved oxygen possibly through reducing surface aeration and wave actions that could facilitate rapid absorption of atmospheric air into the water and this agrees with earlier studies of Welcomme (1985) who documented that vegetation cover on a water surface reduces dissolved oxygen. The significant differences in the oxygen levels among habitat types observed in this study could be attributed to differences in the water currents; water depths and vegetation cover characteristics that characterized the habits.

Vertically dissolved oxygen showed a progressive decrease from the water surface to the bottom, a phenomenon that could be attributed to constant absorption of oxygen at the water surface and uptake of the dissolved oxygen by living organisms and chemical processes at bottom of the water. This observation is in agreement with the earlier finding of Beadle (1981) who documented that in tropical water bodies dissolved oxygen shows a progressive decrease from water surface to the bottom and similarly Wetzel (1983) documented that the surface water is kept at a higher dissolved oxygen concentration by constant diffusion at the air-water interface, all support the findings in the current study.

Temperatures on the other hand showed no significant differences among habitat types possibly because of constant water flows or currents in the river channel that helped to distribute the heat energy absorbed at the water surface more or less uniform in the river. The pH of water did not vary significantly among the habitats types and the average value in all habitat types was 7. 04 indicating that the river water was nearly neutral and this agrees with earlier studies in Savannah Rivers (Welcomme, 1985; Golterman, 1978). The general decreasing pH associated with increasing depth could possibly be the effect of decomposition of organic matter at the basement of water. Wetzel (1983) mentioned high production of carbon dioxide in the bottom waters by the aerobic decomposition and some reducing substances in the mud which cause relative decrease in pH values.

5.1.2 Distribution and abundance of fish

Oreochromis niloticus was found distributed in varying magnitudes in all the four habitat types indicating that the species occupies a wide range of habitats ranging from open waters to plant beds and water hyacinth fringed areas in the river which is in agreement with earlier studies of Hickey and Bailey (1987) on the species in Sudan sudd areas of River Nile. Furthermore Ribbink & Lewis, (1981) showed that some species of fish show high preference while others show broader habitat preference which also agrees with the current study. The variations in the relative abundance of *O. niloticus* in different habitat types could possibly be attributed to abiotic and biotic factor variations. The biotic factors though not addressed in this study may include presence and abundance of planktons and benthic organisms which *O. niloticus* eats either from the bottom sediments or surface waters while the abiotic factor may be water temperature, dissolved oxygen concentration, transparency, flow speed, depth and vegetation cover types which influence the distribution of fish species in water (Busulwa, 1993). It was possible that some habitats had more favourable conditions than others. The variation could also be the effect of inter specific competition for the same niche and predator influences on the species in different habitats (Busulwa, 1993).

There was relatively higher abundance of immature fishes of length size ≤ 20 cm TL and fewer bigger size fishes in *V. cuspidata* , *E. crassipes* and *P. mauritianus* habitats during the study period. This is an indication that macrophytes play important role in providing suitable habitat for fish breeding, nursery grounds and shelter against enemies which is in agreement with earlier studies of Welcomme (1985) who documented the importance of inshore zones in providing both nursery and spawning grounds for fish as the inshore areas are mainly colonized by young fish. The low abundance of *O. niloticus* in *P. mauritianus* dominated shore waters possibly suggests the unsuitability of fast flowing waters for *O. niloticus* which characterized this habitat type.

5.1.3 Population structure and condition factor

The greatest proportion of fish population in all the sampled habitat types was of length size ≤ 24 cm TL with fewer bigger size fish >28 cm TL and this could possibly be due to the frequent cropping of bigger sized fish in the littoral zones by fishers as inshore areas between 0 -50 metres are frequently and intensively fished with different types of fishing gears including the use of small mesh sized gill nets and beach seines commonly observed during the study period that possibly led to reduction in fish sizes. There were significant variations in the condition factor among habitat types with highest mean values in open water habitat and least values in *V. cuspidata* indicating that the different habitat types in Albert Nile were not the same in terms of food availability, abundance, seasonality and other environmental factors that affect organism's growth. Babiker & Ibrahim (1979) earlier documented that differences in food availability, seasonality, temperature and photoperiods which differ in different localities affect organism's growth and its well-being in an environment.

It was also noted that the condition factor (K) values for males and females in the same habitats and age groups showed significant differences with higher K values in males than in females. This probably indicated that males are generally heavier per unit length than females of the same age group. However, earlier studies by Weatherly (1985) indicated that during breeding period, female tilapia tend to starve for weeks while incubating eggs and protecting the fry in the mouth cavity and this lowers the condition factor in females. Further more Lagler (1952) and Kotos (1998) explained that sexual differences, age, changes in seasons, gonad maturity levels and nutritional levels of fishes influence the condition factor (K) values. The open water population had the highest mean K value compared to vegetated shore areas such as *V. cuspidata*, *E. crassipes* and *P. mauritianus* possibly open water habitat supports growth and life of fish better than the shore waters.

5.1.4 Sex ratio of *O. niloticus* in Albert Nile

In this study the overall sex ratio males: females for *O. niloticus* differed from the normal expected ratio of 1: 1 indicating that females and males were different in numbers in upper part of Albert Nile with greater proportion of the population comprising of females. The variation in sex ratio could possibly occur because once fertilization has been concluded males tend to go away from the spawning areas towards feeding areas of the shallow offshore water where they are more frequently captured by fishermen. The females possibly remain in the submerged vegetation in the shallow near shore areas to carry out the incubation and protection of the young to avoid predators (Gomez-Marquez, *et. al.*, 2003; Pena- Mendoza, *et. al.*, 2005). The use of our experimental gill nets in the inshore areas could result in the catches being biased towards the females. The greater number of females in the study area than male counterparts is a good indication of the high potential of the fishery to sustain itself if the resources are properly managed.

5.1.5 Sexual maturity and fecundity of *O. niloticus*

In this study, the sizes at first maturity for females and males in Albert Nile were smaller compared to populations in other water systems showing that the species exhibits relatively rapid maturation in this river system. The relatively small size at first maturity for *O. niloticus* observed in this study could possibly represent a strategy to maximum reproduction in response to high levels of fish mortality due to fishing activities which intensively crops the fish populations coupled with other nonhuman predator effects. The Albert Nile fishery is currently experiencing fishing pressure from unlimited fishing activities. It is therefore possible that *O. niloticus* may be responding towards over fishing through early maturation and reproduction in life to ensure their continued existence. Earlier studies indicated that tilapia living in stressful environments often exhibit earlier maturation in life and protracted reproductive periods as a means of maximizing reproductive success (Charlesworth & Leon, 1976) and such behaviours are possibly linked to a population response towards over fishing (Cowx, *et. al.*, 2003) and both views support the current observations in Albert Nile system. Varying maturation sizes for *O. niloticus* were found by earlier studies in other river systems (Nalyankuma, *et. al.*, 19989; Gomez-Marquez, *et al.*, 2003; Eslyad, *et al.*, 1993; Babiker & Ibrahim, 1979). Lowe-McConnel (1991) found broad range in sizes of *O. niloticus* at first maturity in several East African waters and asserted that the species delays maturation in large Lakes and breeds much younger in small water bodies such as rivers, crater lakes, lagoons and ponds which agree with the current study. Trewavas (1983) found that the maturation size of *O. niloticus* was 24 cm TL in Lakes George and Victoria, 25 cm TL in Lake Edward and 28 cm TL in Lake Albert. Similarly Balirwa (1998) found that the length at first maturity of Nile tilapia in the littoral habitats of Lake Victoria was 24 cm TL for both sexes and in Lake Kyoga it was 23cm and 36 cm TL for males and females respectively. These differences in maturation sizes possibly arise because sexual maturity is a function of size and may be influenced by abundance, seasonality, and availability of food and other environmental factors that affect organism's growth such as temperature and photoperiods, which differ in different localities.

In this study, the observed number of eggs per female ranged from 412 to 2380 eggs with an overall mean fecundity of 854 oocytes which is lower compared to the findings of other investigators on the same species elsewhere. Generally female tilapia produces only a few hundreds of off springs per spawn as females tenaciously protect their offspring for several days after incubation to ensure survival in the wild (Pullin, 1991), a strategy parents use to ensure that majority of their eggs survive to the juvenile stages (Moyle & Cech, 2000). The low fecundity of *O. niloticus* in Albert Nile could probably be a result of combination of different factors such as food abundance, the quality of food and small sizes at maturity of the brooding females as asserted by Winberg (1971). Fryer (1972) obtained a fecundity of 3706 eggs from female of size 57 cm total length, while Elsyayed, *et. al.,* (1993) reported fecundity of 1,511 eggs per female in Shanawan drainage canal in Egypt and 1562 eggs per female in White Nile. These findings therefore confirm that fecundity in *O. niloticus* is variable (Trewavas 1983) and that fecundity correlates with body length and body weight (Babiker & Ibrahim, 1979).

The egg bearing females and the ripe stage IV and V males were collected monthly with greater numbers in April and May especially in *V. cuspidata* and open water habitats which seem to suggest that gonad development proceeded uninterrupted throughout the period of the study and is in agreement with the earlier finding of Gomez-Marquez, *et al.,* (2003) who documented that most Tilapia species breed continuously throughout the year with increased breeding activity during periods of intense sunshine or rain fall. Trewevas (1983) also indicated that there were no obvious seasonal peaks for spawning in *O. niloticus* but spawns throughout the year to compensate the high production of off springs in a single spawn.

5.2 CONCLUSIONS

- The study established that the inshore environment in Albert Nile is characterised by diverse habitat types ranging from open water areas to various vegetation cover types that provide suitable habitats for fish. The habitats were further characterised by shallow, slow flowing, warm water of average temperature 28.4ºC, and high dissolved oxygen with mean concentration of 6.4 mg/l, and pH oscillating around neutral value (7.04) which makes it suitable environment for fish habitation.
- The habitats occupied by *O. niloticus* in Albert Nile differed in terms of physical and chemical characteristics which influenced the distribution, abundance, condition factor, sex ratio and the size classes. *Oreochromis niloticus* occupied all the four habitat types studied in Albert Nile despite differences in the physicochemical characteristics of the habitats which therefore confirms that *O. niloticus* occupies a wide range of habitats ranging from open waters to plant beds and *E. crassipes* fringed areas.
- The young immature *O. niloticus* were mainly associated with vegetated shore areas of *V. cuspidata,* and *E. crassipes* while the mature fish were dominant in the open water areas. This therefore indicates that the fringing macrophytes in the inshore waters are critical habitats for fish breeding, nursery grounds and shelter against fish predators and Juvenile fishes are abundant in the near shore waters and therefore when fishing is intensified in these waters, catches are dominated by immature individuals.

- The condition factor of *O. niloticus* varied among habitat types in Albert Nile suggesting that these habitat types were not the same level of food availability and abundance and that feeding ability differed for the same species in the different habitat types. The open water habitat particularly had better conditions to support the life of fish in terms of food resources than the vegetated water areas.
- Multiple size classes of juveniles were monthly collected during the sampling period with no significant seasonal variations in abundance of size groups in all the habitat types hence there was successful recruitment of the young throughout the period. The Female dominated population of *O. niloticus* in the study area, coupled with relatively rapid maturation of the species in the river is a good indication of high potential of the fishery to sustain itself if properly managed.
- *Oreochromis niloticus* in Albert Nile exhibits relatively rapid maturation in this part of Albert Nile as compared to populations in other systems and this fast maturation possibly represents a strategy to maximum reproduction in response to high levels of fishing pressure and other nonhuman predator effects. The relatively low fecundity of *O. niloticus* in this part of Albert Nile (mean fecundity of 854 eggs per female) could be associated with small sizes of broods and the species habits of parental care as *O. niloticus* is a mouth brooder .

5.3 RECOMMENDATIONS

- Fishing should be prohibited in the near shore waters (0 - 50 metres), lagoons and vegetated covers because these are critical habitats for fish. Such areas should be gazetted as protected or conservation areas for fish breeding and nursery grounds.
- Clearing of fringing shoreline macrophytes should be prohibited.

- The critical habitats should be protected against bad fishing methods such as seining, cast netting, use of small mesh size gill nets and beating of water that have destructive affects on the recruitment, growth and development of the fish species that depend on the inshore areas.
- The size at first maturity obtained in this study should be used to determine the appreciate mesh sizes of gill nets suitable for harvesting *O. niloticus* and controlled mesh sizes of gill nets should be enforced for sustainable harvesting of the fisheries resources in the river. Controlled fishing especially through closed fishing seasons should also be instituted especially during peak breeding seasons (May and July) so as to protect the young stock and the broods from being fished. This will go a long way in ensuring reduced fishing pressure on the resources and promote the sustainability of the fisheries.
- Detailed feeding study to capture other interacting organisms in food chain is also recommended for future studies to understand the food chain or food web dynamics and habitat utilization of Albert Nile.
- The association between water quality parameters and reproductive biology and some aspects of fish ecology of *O. niloticus* were observed over a short intensive studies limited to short stretch of Albert Nile. However, long term studies are ideal to incorporate annual and seasonal variations of the water quality parameters and spatial and temporal changes in habitat utilization.

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APPENDICES

Appendix 1: Analysis of variance for the comparison of temperature values among habitat types in Albert Nile (January – July, 2007)
Two – way ANOVA without replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	113.1	28.275	1.029167
Row 2	4	120.2	30.05	0.83
Row 3	4	115.2	28.8	0.06
Row 4	4	108.1	27.025	0.5625
Row 5	4	116.1	29.025	1.789167
Row 6	4	108.7	27.175	0.109167
Row 7	4	107.3	26.825	0.295833
Column 1	7	196.6	28.08571	1.428095
Column 2	7	200.9	28.7	2.323333
Column 3	7	194.6	27.8	1.563333
Column 4	7	196.6	28.08571	2.374762

ANOVA TABLE

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	35.13357	6	5.855595	**9.578773**	8.48E-05	**2.6613**
Columns	3.023929	3	1.007976	**1.64888**	0.213488	**3.1599**
Error	11.00357	18	0.61131			
Total	49.16107	27				

Appendix 2: Analysis of variance for the comparison of dissolved oxygen values among habitat types in Albert Nile (January – July, 2007)

Two – way ANOVA without replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	22.33	5.5825	0.08015
Row 2	4	22.2	5.55	1.02246
Row 3	4	23.84	5.96	1.20346
Row 4	4	22.33	5.5825	1.15615
Row 5	4	23.54	5.885	1.29056
Row 6	4	25.49	6.3725	0.94769
Row 7	4	36.43	9.1075	0.54849
Column 1	7	44.47	6.352857	2.01549
Column 2	7	37.09	5.298571	2.03058
Column 3	7	44.3	6.328571	1.50281
Column 4	7	50.3	7.185714	1.99766

ANOVA TABLE

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	39.06694	6	6.511157	**18.8658**	7.28E-07	**2.6613**
Columns	12.53466	3	4.178219	**12.1062**	0.00014	**3.1599**
Error	6.212343	18	0.34513			
Total	57.81394	27				

Appendix 3: Analysis of variance for the comparison of maximum water depth among habitat types in Albert Nile (January – July, 2007)

Two – way ANOVA without replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	490	122.5	145.666
Row 2	4	467.7	116.925	189.622
Row 3	4	450.6	112.65	203.29
Row 4	4	473.4	118.35	325.156
Row 5	4	490	122.5	468.333
Row 6	4	515	128.75	509.583
Row 7	4	540	135	626
Column 1	7	918	131.1429	148.809
Column 2	7	702.7	100.3857	40.4947
Column 3	7	816	116.5714	7.95238
Column 4	7	990	141.4286	146.952

ANOVA TABLE

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	1362.164	6	227.027	**5.81218**	0.00162	**2.6613**
Columns	6699.867	3	2233.28	**57.1749**	2.12E-09	**3.1599**
Error	703.0907	18	39.0606			
Total	8765.121	27				

Appendix 4: Analysis of variance for the comparison of water transparency among habitat types in Albert Nile (January – July, 2007)

Two – way ANOVA without replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	230	57.5	9.66667
Row 2	4	220	55	5.33333
Row 3	4	215	53.75	2.91667
Row 4	4	206	51.5	9.66667
Row 5	4	205	51.25	24.9167
Row 6	4	194	48.5	15
Row 7	4	179	44.75	10.9167
Column 1	7	346	49.42857	48.6191
Column 2	7	357	51	4.66667
Column 3	7	364	52	27.3333
Column 4	7	382	54.57143	13.9524

ANOVA TABLE

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	430	6	71.66667	**9.3867**	9.65E-05	**2.6613**
Columns	97.82143	3	32.60714	**4.2707**	0.0192	**3.1599**
Error	137.4286	18	7.634921			
Total	665.25	27				

Appendix 5: Analysis of variance for the comparison of water conductivity among habitat types in Albert Nile (January – July, 2007)
Two – way ANOVA without replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	921.9	230.475	2997.982
Row 2	4	974.1	243.525	1047.369
Row 3	4	1154.7	288.675	644.2225
Row 4	4	1054.8	263.7	967.2933
Row 5	4	802.4	200.6	868.3467
Row 6	4	787	196.75	84.91667
Column 1	6	1313	218.8333	1180.967
Column 2	6	1531.8	255.3	1582.768
Column 3	6	1318.9	219.8167	3226.242
Column 4	6	1531.2	255.2	1557.088

ANOVA TABLE

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	25651.49	5	5130.29	**6.36839**	0.002	**2.9013**
Columns	7746.565	3	2582.19	**3.2053**	0.053	**3.2874**
Error	12083.83	15	805.589			
Total	45481.89	23				

Appendix 6: Analysis of variance for the comparison of water pH among habitat types in Albert Nile (January – July, 2007)
Two – way ANOVA without replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	27.96	6.99	0.017667
Row 2	4	28.19	7.0475	0.114625
Row 3	4	28.68	7.17	0.425267
Row 4	4	27.03	6.7575	0.007825
Row 5	4	26.97	6.7425	0.009492
Row 6	4	30.98	7.745	0.018833
Row 7	4	30.22	7.555	0.032167
Column 1	7	48.97	6.99571	0.237929
Column 2	7	50.42	7.20286	0.142457
Column 3	7	49.19	7.02714	0.141124
Column 4	7	51.45	7.35	0.279233

ANOVA TABLE

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	3.4976	6	0.5829	**8.0294**	0.0003	**2.6613**
Columns	0.5708	3	0.1902	**2.6208**	0.0823	**3.1599**
Error	1.3068	18	0.07260			
Total	5.3753	27				

Appendix 7: The monthly mean temperature variations in the surface and bottom waters of different habitat types in Albert Nile (January – July, 2007)

	Vossia		*Eichhornia*		*Phragmites*		Open water	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
J	26.3	26.1	28.6	28.6	27.3	27.0	28.6	28.3
F	28.8	28.6	29.2	29.0	29.1	29.1	28.7	28.6
M	29.4	29.1	31.0	31.0	29.8	29.7	30.0	30.0
A	28.6	28.4	29.4	29.3	28.6	28.3	29.7	29.6
M	30.9	30.6	32.0	32.0	30.2	30.0	31.0	31.0
J	27.5	27.4	27.6	27.0	26.5	26.4	27.8	27.7
J	27.1	27.0	27.4	26.8	27.0	27.0	27.3	27.0

Appendix 8: The monthly mean dissolved oxygen variations in the surface and bottom waters of different habitat types in Albert Nile (January – July, 2007)

	Vossia		*Eichhornia*		*Phragmites*		Open water	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
J	5.4	5.0	5.6	5.2	5.73	5.42	5.9	5.9
F	5.9	5.4	4.4	4.3	5.2	5.2	6.8	6.7
M	6.8	6.6	4.5	4.3	6.09	6.0	6.2	6.1
A	5.8	5.6	4.5	4.2	5.7	5.6	6.8	6.7
M	5.2	4.9	4.8	4.8	5.6	5.6	6.1	5.9
J	5.8	5.6	5.2	5.0	6.1	6.0	7.4	7.5
J	9.1	8.9	8.3	8.1	8.9	8.8	10.1	9.8

Appendix 9: The monthly mean pH variations in the surface and bottom waters of different habitat types in Albert Nile (January – July, 2007)

	Vossia		*Eichhornia*		*Phragmites*		Open water	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
J	7.2	6.6	6.93	6.74	6.86	6.42	7.42	7.4
F	6.9	6.4	7.4	6.9	7.3	6.9	7.3	7.1
M	6.6	6.2	7.1	6.9	7.09	7.0	7.8	7.4
A	6.8	6.6	7.4	6.8	7.05	6.7	6.9	6.7
M	7.0	6.8	6.9	6.8	6.9	6.7	7.9	7.7
J	7.7	7.6	7.8	7.4	7.7	6.9	7.5	7.2
J	7.4	7.1	7.6	7.2	7.4	7.1	7.1	7.0

Appendix 10: Monthly fish catch in different habitat types in Albert Nile (January-July, 2007

Month	*Vossia*	*Eichhornia*	*Phragmites*	Open water
J	27	18	15	23
F	36	29	19	29
M	13	14	6	20
A	53	17	6	24
M	35	19	8	27
J	19	17	11	24
J	26	20	14	17
Total	209	134	89	164
%	35.1	22.5	14.9	27.5

Appendix 11: Correlation of fish abundance and water quality parameters by habitat types

Variables	*Vossia*	*Eichhornia*	*Phragmites*	Open water
Depth	0.64	0.5	0.7	0.6
Transparency	0.5	0.3	0.4	0.8
Temperature	0.6	0.6	0.6	0.5
Dissolved oxygen	0.4	0.3	0.6	0.7
Conductivities	0.4	0.2	0.4	0.5
pH	0.1	0.2	0.2	0.1

Appendix 12: Length frequency distribution of *O. niloticus* in different habitat types in Albert Nile (January- July, 2007)

Habitat	*Vossia*		*Eichhornia*		*Phragmites*		Open water		Total
Size class	No.	%	No.	%	No.	%	No.	%	No.
0- 4	5	2	4	2	2	2	0	0	11
4- 8	8	4	14	11	4	5	5	3	31
8-12	49	24	31	23	24	27	14	9	118
12-16	40	19	39	29	22	25	22	13	123
16-20	68	33	30	22	19	21	40	24	157
20-24	31	15	14	10	13	15	50	31	108
24-28	8	4	2	2	3	4	24	15	37
28-32	0	0	0	0	1	1	4	2	5
32-36	0	0	0	0	0	0	3	2	3
36-44	0	0	0	0	0	0	2	1	2

Appendix 13: Monthly size class distribution in different habitat types in Albert Nile (January- July, 2007)

Habitat types	Size class (cm)	Months J	F	M	A	M	J	J	Total
V. Cuspidate	0-4	3	2	0	0	0	0	0	5
	4-8	2	1	1	3	1	0	0	8
	8-12	6	16	5	4	7	2	10	49
	12-16	8	10	0	10	5	5	4	40
	16-20	2	2	4	24	14	10	10	68
	20-24	4	2	2	10	6	4	6	31
	24-28	2	2	1	1	0	0	0	8
	28-32	0	0	0	0	0	0	0	0
E. Crassipes	0-4	2	0	1	0	0	1	0	4
	4-8	3	8	1	2	0	0	0	14
	8-12	3	2	3	4	7	7	5	31
	12-16	5	7	1	4	9	5	8	39
	16-20	7	4	5	4	1	4	5	30
	20-24	0	5	4	2	2	0	1	14
	24-28	0	1	0	1	0	0	0	2
P. mauritianus	0-4	1	0	0	0	1	0	0	2
	4-8	0	2	1	0	0	0	1	4
	8-12	3	6	0	1	6	6	2	24
	12-16	3	1	0	3	7	3	5	22
	16-20	3	4	2	1	3	4	2	19
	20-24	4	3	2	1	0	0	3	13
	32-36	2	0	1	0	0	0	0	3
	36-40	0	0	1	0	0	0	0	1
Open water	0-4	0	0	0	0	0	0	0	0
	4-8	0	2	1	0	0	0	0	3
	8-12	4	5	2	3	0	0	0	14
	12-16	8	5	6	0	0	3	1	23
	16-20	8	7	5	4	6	3	7	40

	20-24	2	4	5	8	11	10	10	50
	24-28	0	1	8	5	4	7	0	25
	28-32	0	0	0	3	0	1	0	4
	32-36	0	0	2	1	0	0	0	3
	36-40	0	0	1	1	0	0	0	2

Appendix 14: Monthly frequency of various gonad stages in female *O. niloticus* in Albert Nile (January-July, 2007)

Month	Gonad stages				
	II	III	IV	V	VI
January	24	11	7	5	3
February	16	11	5	3	1
March	6	8	10	4	1
April	10	17	10	5	6
May	12	15	8	5	4
June	14	7	5	2	1
July	15	6	8	3	I
TOTALS	97	75	53	27	17
%	36.60	28.3	20.0	10.19	6.42

Appendix 15: Monthly frequency of various gonad stages of male *O. niloticus* in Albert Nile (January- July, 2007)

Month	Gonad stages				
	II	III	IV	V	VI
January	12	7	8	2	4
February	8	10	5	2	1
March	4	6	3	3	1
April	12	9	6	5	5
May	18	6	4	3	4
June	14	5	3	2	1
July	16	4	6	3	2
TOTALS	84	47	35	20	18
%	41.18	23.04	17.16	9.8	8.82

Appendix 16: The relative abundance by (a) Numbers and (b) Biomass of *O.niloticus* in different habitats in Albert Nile, January- July, 2007.

Habitat type	Number of fish	Total weight (g)
Vossia cuspidata	209	22,125
Eichhornia crassipes	134	12,251
Phragmites mauritianus	89	9878
Open water	164	34,186
Total	596	78,440

Appendix 17: Monthly catch of egg producing *O. niloticus* in different habitat types in Albert Nile (January- July, 2007)

Month	Vossia		Eichhornia		Phragmites		Open water	
	No. female	Eggs	No.female	Eggs	No. female	eggs	No. female	Eggs
J	2	1644	1	524	1	774	3	2662
F	1	778	1	584	0	0	4	2735
M	1	868	2	1116	3	2788	8	9315
A	10	10203	1	546	1	760	8	5276
M	5	4158	3	1864	0	0	3	1868
J	1	708	3	1912	0	0	4	2403
J	6	3868	0	0	0	0	0	0
Totals	26	22227	11	6546	5	4322	30	24259
Fecundity		855		595		864		809

Appendix 18: Correlation of fecundity with body parameters of *O. niloticus* and Environmental variables in Albert Nile (January- July, 2007)

Variables	*Vossia*	*Eichhornia*	Open water
Temperature	R = 0.8	R = 0.7	R = 0.6
Dissolved oxygen	R = -0.7	R= -0.8	R = 0.1
Ph	R = 0.1	R = 0.5	R = 0.4
Conductivity	R = 0.4	R = 0.4	R = 0.4
Body length	R= 0.734	R= 0.7	R= 0.73
Body weight	R = 0.876	R= 0.876	R= 0.876

Appendix 19: Relationship between fecundity, body Length and body weight of *O. niloticus* in Albert Nile (January – July, 2007)

Parameter	No. of fish	Relationship	Correlation	P
Body length	71	$F = 7.98\ L^{1.456}$	R= 0.876	< 0.01
Body weight	71	$F = 38.3\ W^{0.564}$	R = 0.734	< 0.01

Appendix 20: Cumulative frequency distribution of length groups in male *O. niloticus* of maturity stages IV and V in Albert Nile (January-July, 2007)

Length (cm)	Frequency (No.)	Cumulative frequency	Percentage (%)
17	1	1	1.3
18	3	4	5.3
19	8	12	16
20	6	18	24
21	11	29	38
22	14	43	57
23	6	49	65
24	7	56	77
25	3	59	78
26	8	67	88
27	6	73	96
28	1	74	98
29	2	76	100

Appendix 21: Cumulative frequency distribution of length groups in female *O. niloticus* of maturity stages IV and V in Albert Nile (January- July, 2007)

Length (cm)	Frequency (No.)	Cumulative frequency	Percentage(%)
17	2	2	3
18	6	8	11
19	3	11	15
20	9	20	27
21	11	31	42
22	16	47	64
23	6	53	72
24	6	59	82
25	2	61	88
26	6	67	91
27	2	69	93
28	0	69	93
29	2	71	96
30	0	71	96
31	1	72	97
32	1	73	99
33	1	74	100

Appendix 22: Data sheet for recording fish bio data.

Landing site………………….. Study site…………… sampling date………….

Id No. of fish.	TL (mm)	Wt (g)	Sex	Gonad stage	No of eggs	Stomach fullness	

Appendix 23: Data sheet for physicochemical parameter of water

Landing site……………………………… Study site………………….……………

Water depth	Temp.	Dissolved oxygen	pH	Conductivity	Secchi depth	Flow speed	Date of record

Appendix 24: Categorization of gonad stages in *O. niloticus*

Maturity status of each fish was determined and assigned as stages I, II, III, IV, V and VI according to Legendre and Dupenchelle (1996) procedures where;

Stage I comprised of immature or virgin fish. Both sexes had non active gonads and under a magnifying lens looked very small, thin or thread like occupying a small part of the body cavity;

Stage II was the early maturing phase/ fish beginning maturation;

Stage III was the developing stage where in females, minute eggs whitish in colour appeared in an expanded ovary that occupies about two thirds of the abdominal cavity and in males the testes were enlarged and increased in volume, flat in appearance;

Stage IV was the pre spawning stage where ripen eggs yellowing in colour appeared in female ovaries occupying almost entire body cavity and in males, the testes became more whitish in appearance;

Stage V was the spawning stage where gametes were seen flowing. In females the transparently yellow ripened eggs loosened from the ovary wall were visible through the ovarian wall and some were seen flowing with slight pressure on the abdomen. In males the testes looked thicker and expanded and milt was seen flowing out with slight pressure on the abdomen;

Stage VI was of post spawning individuals whose gonads were spent already. In both cases gonads looked shrunken. Ovaries were flaccid sac like and reduced in volume but contained some of the un- spawned eggs and a large number of un- ripened small ova.