Diet And Feeding Ecology Of Nile Tilapia, Oreochromis Niloticus And Nile Perch, Lates Niloticus In Protected And Unprotected Areas Of Lake Victoria, Tanzania

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Abstract: Diet and feeding ecology of *O. niloticus* and *L. niloticus* in Rubondo Island National Park (RINP) an area protected from fishing and Kome Island (KI) an area unprotected from fishing activities in Lake Victoria were compared. Important food items of *O. niloticus* and *L. niloticus* both in RINP and KI areas did not differ. Main food items of *O. niloticus* were detritus, remains of water hyacinth and phytoplanktons. Phytoplanktons in *O. niloticus* stomachs were from five classes of Cynanophyceae, Basillariophyceae, Chrolophyceae, Dinophyceae and Euglenophyceae. Class Cyanophyceae had the highest number of occurrences than any of the phytoplankton observed in the stomachs of *O. niloticus*. The percentages of occurrences were 65.96, 24.2, 9.61, 0.01 and 0.01 for Cyanophyta, Chlophyta, Diatom, Euglenophyta and Dinophyta respectively. High indices of relative importance (IRI%) of haplchromine fishes in L. niloticus stomachs in both areas show that L. niloticus has returned to its original food of haplochromine fishes as it was during its upsurge in Lake Victoria. The indices of relative importance (IRI %) of haplochromine fishes for L. niloticus in KI and RINP areas were 95.3% and 87.3% for KI and RINP areas respectively. The second important prey was Caridina nilotica with indices of relative importance of 1.2% and 12.7% for KI and RINP areas respectively. Insects were important food of juvenile L. niloticus. Cannibalism of L. niloticus occurred in both areas.

Keywords: Detritus, Caridina nilotica, Haplochromis spp, Stomach contents, Lates niloticus, Orechromis niloticus, Phytoplanktons.

1 Introduction

O. niloticus is an omnivore; its foods include plants, insects, diatoms and algae (Batjakas et al. 1997; Njiru, 2004). Habitats and geographical positions tend to dictate on food items to be ingested by a fish species. For example, Banikwa et al. (2006) observed that O. niloticus in Lake Nabugabo had different food items in different habitats. In the inshores of Lake Victoria, O. niloticus is mostly found at depths ranging from 0- 20 m (Njiru et al., 2006). On the other hand matured, L. niloticus is a demersal fish foraging in pelagic areas. While, juveniles of L. niloticus are numerous in the wetlands, open and deep water areas (Ligtvoet et al., 1988). Feeding habits of L. niloticus in Lakes Victoria, Chad, Turkana and Chamo have been reported by (Acere, 1985; Dadebo et al., 2005). The authors reported that haplochromine fishes were the main diets of L. niloticus in Lake Victoria. As haplochromine fishes became reduced in the eighties, the Lates shifted to Rastreneobola argentea, C. nilotica and juvenile L. niloticus (Ligtvoet, et al., 1988). In Lake Chad, Schilbeids were the most important prey of adult Lates; In Lake Turkana, cyprinids and cichlids were the most important prey of the Lates fish whereas, in Lake Chamo cyprinid fish, Labeo horie was the most important prey for adult and juvenile Lates (Dadebo et al., 2005). Ogutu-Ohwayo (2004) reported that important food items of L. niloticus in Lakes Victoria, Kyoga, Nabugabo, and Albert from 1964- 2000 had been changing from haplochromine fishes to R. argentea, C. nilotica, anisopteran nymphs, tilapiine fishes, juvenile L. niloticus and Alestesspp. C. nilotica being important prey ingested by wider size ranges of L. niloticus. Investigations on food and feeding habits of O. niloticus and L. niloticus in Lake Victoria were conducted at the onset of L. niloticus in the lake (Acere, 1985; Ligtvoet et al., 1988). Species of O. niloticus and L. niloticus have been explained to out compete the native fish species in Lake Victoria (Acere, 1985) and therefore, the disappearance of native fish species is associated with the introduction of L. niloticus but other reasons could be responsible for the disappearance of 200+ species of cichlids (Njiru et al., 2008). The increase of O. niloticus in the catches from Lake Victoria has been explained to utilize vacant niches left by disappeared small sized cichlid species (Njiru et al., 2008). The above researches did not compare the feeding ecology of O. niloticus and L. niloticus between the two areas as in the present study which investigates and documents on the feeding ecology of O. niloticus and L. niloticus in Rubondo Island National Park (RINP) an area protected from fishing activities and Kome Island (KI) an area unprotected from fishing activities in Lake Victoria.

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2 Materials and Methods

2.1 Study site

Lake Victoria is situated close to the Equator between latitudes 0º 20′ N to 3º 0′ S, and longitudes 31º 39′ E to 34º 53′ E at an altitude of 1,134 m above the sea level (Welcomme, 1970). This study was conducted at Rubondo Island National Park (RINP) and Kome Island (KI) (Figure 1).

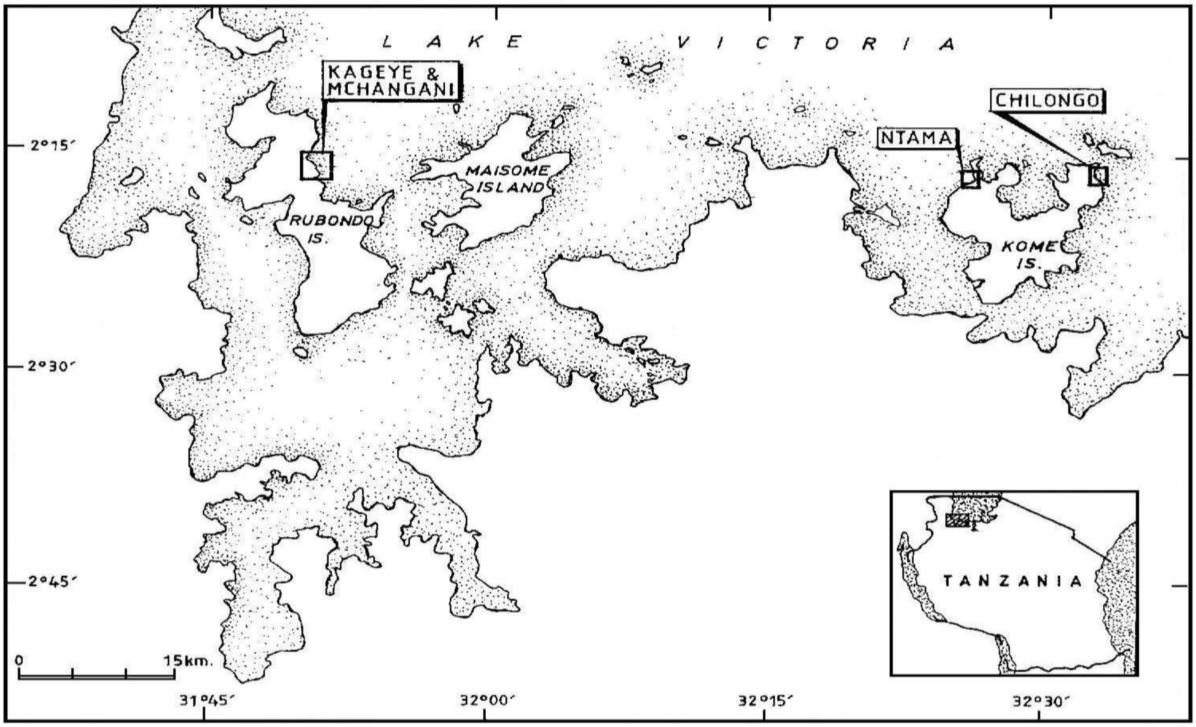

Figure 1. Lake Victoria showing sampling sites around Rubondo and Kome Islands

RINP has an area of 457 km^2 comprising of nine islets; it was gazetted in 1977 to become a national park for conservation of indigenous wildlife which include; crocodiles, hippos, bushbucks, velvet monkeys, sitatungas, genet cats and otters. Introduced animals are elephants, chimpanzees, giraffes, black and white colobus monkeys, sunni and grey parrots. Fish samples of the current study from RINP were collected from Kageye and Mchangani sampling sites, while samples from KI were collected from the sites of Ntama and Chilongo. Distance between KI and RINP is about 70 km.

2.2 Fish collection

Specimens of O. niloticus and L. niloticus were collected monthly by using a beach seine net (146 m x 4.75 m) and 10 mm stretched mesh size at the cod end. Weight measurements for each fish were recorded after blotting fish samples for the total weight (TW) by using a top loading balance to the nearest 0.1 g. Total length (TL) was measured from the most anterior part of the fish to the tip of the longest caudal fin for L. nilotcus and to end of the caudal fin which is round for O. niloticus. Fish samples were collected during day time when fishes were actively feeding (Teferi et al., 2000; Goudswaards et al., 2004). Fish samples were dissected using a sharp knife. Specimens of O. niloticus and L. niloticus with food contents in their stomachs were considered for stomach analysis and their stomachs were preserved in 4% formalin in cross referenced bottles. The stomachs were tied using pieces of thread at fore and hind parts of stomachs. In the Laboratory, for specimens of L. niloticus each stomach was cut open and its contents were poured in a Petri dish, the number of prey organisms identified to the lowest possible level and their weights recorded to 0.01g. An index of Relative Importance (IRI) for each prey was determined by using the formula % IRI = (%N+%W)* %F (Cortes, 1997; Hyslop, 1980; Rodriquez et al., 2011). Where, % N was the number of individuals for each prey category recorded in all food items expressed as the percentage of the total number recorded for food items which was calculated from the following formulae,

$$\% N = \frac{\text{Total nimber of item i}}{\text{Total number of identified food items}} \times 100$$

% W is the percentage weight of each prey recorded for all stomachs in relation to all stomachs was calculated as % W

$$= \frac{\text{Total of food item } i}{\text{Total weight of food items}} \times 100$$

While, % F was the number of stomachs in which each prey item occurred and expressed as a percentage of the total number of stomachs i.e.

$$\% F = \frac{\text{Total stomachs having food item } i}{\text{Total stomachs with food } i} \times 100$$

The % IRI is a robust index for comparing food items obtained from % N, % W and % F (Cortes, 1997; Schofield and Chapman, 1999). The percentage Index of Relative Importance of prey items (% IRI) from the stomach contents was calculated by summing up values of IRI for each fish for all food items and then each food item was divided by the sum (Schofield and Chapman, 1999). Stomach fullness index (SFI) was calculated from the formula SFI = 10000 cL^{-3} whereby c is the stomach content in gm and L is the length of fish (TL) in cm (Darbyson et al., 2003). Analysis of stomach contents for specimens of O. niloticus was calculated by use of abundance percentage (Njiru et al., 2005). Stomach contents of O. niloticus were diluted to 100 millilitres, 2 millilitres were drawn and placed under an inverted microscope for identification and counting of phytoplankton from stomachs of O. niloticus at a magnification of 400 x. Twenty five fields were viewed for each 2 millilitres. Keys used for identifying phytoplankton specimens to the lowest taxonomic level possible were (Van Meel, 1954; Holomogren et al. 1971). Vacuity index (%VI) was calculated by the formula %VI = number of empty stomach/Total number of stomachs X 100 (Jardas et al. 2004). Where VI stands for vacuity for index

2.3 Data analysis

Stomach fullness index of O.niloticus and L. niloticus in RINP and KI areas during the study and seasonal stomach fullness indices were tested by using Mann-Whitney U test at $p<0.05$. Kruskal-Wallis test was used to test differences of stomach fullness index of juvenile, female and male L. niloticus in KI at $p< 0.05$. Abundance percentage of phytoplankton species in O. niloticus stomachs were calculated using the formula = Fi∑Fi)*100 where, Fi is the food type i counted in the stomach. Vacuity indexes (%VI) of O. niloticus and L. niloticus in RINP and KI areas were compared by Mann-Whitney U test at $p< 0.05$.

3 Results

3.1 Food types of O. niloticus and L. niloticus

Haplochromis spp. was the main food item of L. niloticus both in RINP and KI. Food items of L. niloticus in the RINP were fish and insects. While, in KI food items were fish, insects and snails. Main food items of O. niloticus in both areas were detritus and plants/ phytoplankton. There were 100 phytoplankton species observed in stomachs of O. niloticus during the study. The observed phytoplanktons during the study were from five classes of Chlorophyceae, Cyanophyceae, Basillariophyceae, Dinophyceae and Euglenophyceae. Euglenophyceae and Dinophyceae were observed in RINP only. Chrolophyceae was the most diverse class among the phytoplankton sampled represented by 40 species (40 %); Basillariophytceae were 35 species (35 %). The third abundant phytoplankton was Cyanophyceae represented by 23 species (23 %) but the numbers of Cyanophyceae species was more numerous than any class. Percentage of occurrences of Cyanophyceae was 65.96; Chlorophyceae was 24.2; Basillariophceae was 9.61; Euglenophyceae and Dinophyceae were represented by a species (1%). Phytoplankton species composition during the rainy season for both areas were 67 and in the dry season were 59 species but did not differ significantly, between the seasons by Mann-Whitney comparison at $U = 1737$, $Z = -1.24$ and $P = 0.21$. Detritus, plants, (Eichhornia crassipes) and algae in stomachs of O. niloticus in KI were observed in fish whose length was 19 cm -28 cm TL. While detritus, plants /E. Crassipes and algae in O. niloticus stomachs in RINP area were observed in fish length ranging from 17 cm - 56 cm TL. Length of L. niloticus with food in their stomachs ranged from 14 cm-152 cm TL and from 17 cm -51 cm TL in RINP and KI respectively. In L. niloticus stomachs in RINP food items were: - Haplochromine fishes were observed in fish length ranging from 14 cm -85 cm TL; Caridina nilotica in fish length from 17 cm -75 cm TL; Rastreneobola argentea were found in fish length ranging from 17 cm -38 cm TL; cannibalism of L. niloticus occurred in fish length ranging from 58 cm-80 cm TL; Odonata and chironomids were observed in fish stomachs with length from 42 cm -58 cm TL. One specimen of L. niloticus with a length of 152 cm TL had an O. niloticus fish weighing 2.7 kg in its stomach. In KI Haplochromis spp were found in stomachs of L. niloticus with length ranging from 20 cm -51 cm TL; C. nilotica in fish stomachs which ranged from 23 cm -35 cm TL; cannibalism of L. niloticus occurred in fish length from 24 cm to 34 cm TL; Odonata nymphs occurred in fish length ranging from 23 cm-30 cm TL; R. argentea were observed in L. niloticus stomach length ranging from 24 cm -32 cm TL; Snail shells were observed in stomachs of fish length ranging from 29 cm -34 TL and insect remains were observed in fish stomachs < 25 cm TL.

3.2Stomach indices of O. niloticus and L. niloticus

Indices of stomach fullness and relative importance were used in studying prey types and quantity of food contents of L niloticus in RINP and KI areas in Lake Victoria presented in Table 1. Mean stomach fullness index was used to study feeding intensity of O. niloticus and L. niloticus from Lake Victoria in RINP and KI areas indicated in Table 2. The seasonal stomach fullness index and stomach emptiness are shown in Table 2. Comparisons of stomach fullness index of O. niloticus and L. niloticus between RINP and KI areas using Mann-Whitney U test are shown in Table 3. O. niloticus in both RINP and KI areas had high percentages of empty stomachs. This could have been caused by regurgitation process of the specimens during hauling in of the beach seine net (Goudswaard et al., 2004). O. niloticus in KI area had higher percentage of empty stomachs than in RINP area at 96% and 94% respectively. Seasonal stomach content indicated that all of the studied species during the dry season had a higher stomach fullness index than during the wet season and the stomach % emptiness was higher during wet season for O. niloticus and L. niloticus (Table 3). Percentage of empty stomachs of L. niloticus in the KI area was 68. In the RINP area the percentage of empty stomachs was 85 (Tables 1). Index of relative importance (IRI%) of L. niloticus indicates that Happlochromis spp were more important preys than other preys both in the RINP area and in the KI area at 95.3% and 87.3% respectively. The second important (IRI %) prey for L. niloticus in RINP and KI areas was C. nilotica at 1.2% and 12.7% respectively. Mean stomach fullness index of O. niloticus in KI area was higher than in RINP area and was significantly different by Mann-Whitney U test at $U = 54$, $Z = -3.127$ and $p= 0.001$. The seasonal stomach fullness index of O. niloticus was not significantly different between the rainy and the dry seasons by Mann-Whitney U test at $U = 20$, $Z = - 0.62$ and $p = 0.53$. Mean stomach fullness index of L. niloticus in the KI area was higher than in RINP area and it was significantly different by Mann-Whitney U test at $U = 2017$, $Z = -3.131$, and $p =0.0013$. The seasonal stomach fullness index of L. niloticus was not significantly different in the RINP and KI areas by Mann-Whitney U test at $U = 2635$, $Z = -0.7$ and $p = 0.48$.

Table 1. *Stomach indices of L. niloticus in RINP and KI areas in Lake Victoria*

RINP			KI		
Food types	SFI	%IRI	Food types	SFI	%IRI
Caridina niloticus	0.14	1.2	Caridina niloticus	0.56	12.7
Haplochromis ssp	0.99	95.3	Haplochromis ssp	1.145	87.3
L.niloticus	1.2	1.1	L.niloticus	1.89	0.001
Odonata	0.06	0.03	Odonata	1.18	0.002
Rastreneobola argentea	1.08	0.7	Rastreneobola argentea	0.38	0.02
O. niloticus	5.4	1.03	Snail	0.39	0.01
Chironomid	0.0002	0.7	Insect (unidentified)	0.175	0.01

Table 2. *Seasonal percentage stomach content, empty stomachs and mean stomach fullness index of O. niloticus and L. niloticus in RINP and KI areas.*

	RINP				KI			
Species	O.niloticus		L. niloticus		O.niloticus		L. niloticus	
Season	Dry	Wet	Dry	wet	Dry	Wet	Dry	Wet
Stomach index								
% Emptiness	91.3	96.9	82.7	88.2	92.5	98.6	47.7	53.8
% stomach content	8.7	3.1	18.3	11.8	7.5	1.4	52.3	46.2
Mean SFI	0.32±0.34		0.35±0.44		1.08±1.03		1.32±1.17	

Table 3. *Mann-Whitney U test on stomach SFI of O. niloticus and L. niloticus in RINP and KI areas.*

Species	Stomach Index	Statistical test	U	Z	P value	Decision
O. niloticus	SFI	Mann-Whitney	52	-3.38	0.0007	Significant
L. niloticus	SFI	Mann-Whitney	1731	-2.49	0.002	Significant

3.3 Food and feeding intensity/activity of O. niloticus and L. niloticus

Comparisons of stomach fullness index (SFI) of food types of O. niloticus in RINP and KI area showed that feeding activity between the two areas was significantly different at $U = 52$, $Z = -3.34$ and $p = 0.0007$. Important food type for L. niloticus in the KI and RINP area was haplochromine fishes. There were no significant difference in food types for L. niloticus in the area and the stomach fullness index (SFI) among females, males and juveniles seasonally were not significantly different (Kruskal- Wallis test at $H = 1.67$ and $p = 0.43$ and $H = 1.15$ and $p = 0.56$) for dry and wet seasons respectively. In the RINP area the most important food type for L. niloticus was haplochromine fish species for females, males and juveniles. The second important food type for females were chironomids; C. nilotica for males and R. agentea for juveniles. Comparisons of the stomach fullness index (SFI) among the females, males and juvenile using Kruskal-Wallis test was not significantly different at $H = 4.5$ and $p = 0.105$.

4 Discussion

4.1Food types of O. niloticus and L. niloticus

Food types of O. niloticus were mainly of plant materials such as remains of water hyacinth; E. crassipes. The water hyacinth is used as a substrate by epiphytic algae and, as the fish forage on the algae they consume even the substrate itself. Detritus as food type of O. niloticus indicates that the species is a bottom feeder. This finding is in agreement with the findings of (Njiru et al., 2004; Adeyemi et al., 2009). The present study indicates that blue green alga is the most numerous species of the phytoplankton observed. This finding is in agreement with the findings of (Lung'Aiya et al., 2000; Njiru et al., 2005; Semyalo et al., 2010). Formally, diatoms were the most diverse and dominant phytoplankton in great lakes of Africa but due to ecological changes, global warming and eutrophication especially in Lake Victoria, bloom forming algae of the blue green algae has become the dominant phytoplankton in the lake since the 1980's (Ndebele – Murisa et al., 2009; Ngupula and Mlaponi, 2010). Occurrences of haplochromine fishes in high quantity in L. niloticus stomachs during the current study could be an indication of L. niloticus is returning to its original prey (Ogutu-Ohwayo, 1990; Mkumbo and Ligtvoet, 1992) therefore, it is imperative to institute management strategies to conserve L. niloticus in Lake Victoria and its preys for example the haplochromine fishes and the freshwater prawn. Important food type for matured L. nilocitus (males and females) in the RINP and KI areas were haplochromine fishes. The second important food type was C. nilotica for the two areas. The important food type for juvenile L. niloticus was also haplochromine fishes in the RINP and KI. There were differences in the second important food type between the KI and the RINP whereby the second important food type of juvenile L. niloticus in KI was C. nilotica while in the RINP the second important food type was R. agentea. The current study shows that juveniles L. niloticus in Lake Victoria feed on invertebrates such as C. nilotica, Chironomids, odonata and other insects. This study shows that the shift of L. niloticus from invertebrates can take place at a small length of 14 cm TL. Earlier it was reported that the shift of L. niloticus from feeding on invertebrates' food types to piscivory food types in Lake Nabugabo was at approximately 30 cm (Schofield and Chapman (1999). In Lake Chamo, Ethiopia shift from invertebrates to piscivore was between 48.5 cm and 73.2 cm (TL) (Dadebo et al., 2005). The general trend of feeding behaviour of L. niloticus in shifting from invertebrates to fishes is determined by what kinds of fish preys are present in a particular area or habitat (Ogari; 1985; Katunzi et al. 2006). The changes in shift in the current study from invertebrate to pisvore could have been influenced with current fishing pressure in the lake accompanied with ecological changes whereby there are also changes in length at first maturity. From these findings it could be postulated that L. niloticus has returned to its former preferred food type of haplochromine fishes as during its upsurge in the eighties (Mkumbo and Ligtvoet 1992; Ngupula and Mlaponi, 2010). It has been reported that some cichlid fish species which were reported to be depleted by L. niloticus in Lake Victoria are now increasing in the present catches of fish in Lake Victoria (Kitchell et al. 1997; Katunzi et al. 2006; Matsuishi et al. 2006). The disappearance of some cichlid fish in the eighties could have been caused by other reasons than the predator L. niloticus.

4.2 Stomach indices of O. niloticus and L. niloticus in RINP and KI of Lake Victoria

O. niloticus in the RINP and KI in Lake Victoria had high percentage of individuals with empty stomachs due to the fishing gear used during the study. Oso et al., (2006) reported that stomach emptiness of O. niloticus in a tropical dam was 32.11% and recommended that cast nets are good gear for collection of fish samples for stomach analysis. Digestion of food materials in fish stomachs could be another reason of having high percentages of empty stomachs at the time of sampling and fixing the stomach samples for stomach analysis (Oso et al. (2006). Feeding of O. niloticus on phytoplankton could also account for high percentage of empty stomachs but the stomachs were virtually having some amount of phytoplankton in their guts which needs aggregation of many phytoplanktons's to visualise the guts as having food contents. Index of relative importance of food of L. niloticus in RINP and KI were Haplochromis spp and the second important food item was C. nilotica. However, there were some differences in terms of preys ingested by the Nile perch during the study in the two areas. Differences of prey types within the areas imply that different areas within the same lake are inhabited with different prey species. This could have been caused by ant predatory behaviour of preys, historic factors, available habitats and ecological adaptation (Keast, 1978: Christensen, and Persson, 1993). Due the reasons above, L. niloticus in different lakes have different important food items. For example, Schoefield and Chapman (1999) reported on the important food items of L. niloticus as R. argentea, Brycynus sadleri, L. niloticus and unidentified fishes and insects of Anisoptera, Zygoptera and Ephemeroptera in Lake Nabugabo. In Lake Chamo, Ethiopia Dadebo et al. (2005) reported on the important food items of the species in the lake to be Labeo horie, O. niloticus, L. niloticus (cannibalism) and Hydrocynus forskahlii. Budeba and Cowx, (2007) reported that C. nilotica was an important prey for L. niloticus in Lake Victoria after the depletion of some cichlids. The vacuity index was high in older specimens as results juveniles in the populations of L. niloticus in KI area indicated high feeding activity/intensity.

4.3 Feeding activity of O. niloticus and L. niloticus

Seasonal stomach content indicates that all the studied species of O. niloticus and L. niloticus had high percentage of empty stomachs and high vacuity index during the wet season. This finding is in agreement with that of Rangarajan (1970) whereby the feeding habits of snapper, Lutjanus kasmira were observed to be active feeding during the North-east monsoon winds. Rangarajan (1970) further states that the snappers were active feeding after the breeding season. The studied fish species of O. niloticus and L. niloticus in the current study indicated that they breed the whole year but, with a peak breeding in the rain season; this shows that in the dry season many individuals are feeding relatively intensively than during the wet season. Individual specimens of O. niloticus and L. niloticus in the RINP had relatively high amount of food in their stomachs than the conspecifics in the KI in all seasons. This finding is in agreement with that of Guidetti, (2006) where he observed that predation of sea archins in protected areas was higher than in unprotected areas. Specimens of L. niloticus in unprotected area were having more stomachs with food than the specimens in the protected area at 32% and 15% for unprotected and protected areas respectively. The empty stomach percentage of L. niloticus in the current study is a bit higher than that reported by Dadebo (2005) on the same species in Lake Chamo, Ethiopia where the empty stomach percentage was 53.8. From this study it is concluded that L. niloticus in KI were more active feeding than in RINP. Moreover, composition of L. niloticus in the KI was more of juveniles than the individuals in the RINP. Juvenile L. niloticus are more active feeders than the grown up L. niloticus a phenomenon found in all fishes; since juvenile's require more energy for growth. El-Sayed (2006) reported that small sized hybrids of tilapias (O. mossambicus x O. niloticus) were more active feeders than larger ones and that feeding intensity and food consumption decreased with increasing in fish size. Amisah, and Agbo, (2008) reported that monthly mean stomach fullness of juvenile Sarotherodon galilaeus multifasciatus were higher and significantly different than older individuals. Ajah, (2010) reported that active feeding in Heterobronchus longifilis larvae decreased with age.

5 Acknowledgements

I wish to thank the European Union (EU) for sponsoring this study during the implementation of a Fisheries Project under the Implementing Agency of the Lake Victoria Fisheries Organization; I extend my gratitude to Mr. John Kagosi for assistance in data collection during the study. My special gratitude goes to Mr. Kessy for identification of phytoplanktons from fish stomachs. Lastly, I thank everyone in one way or another who made this work be completed.

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