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Feeding selectivity of *Oreochromis niloticus* in Lake Naivasha and Oloiden in the Rift Valley, Kenya

Guto Kerubo Carolyne[1*], Njiru Murithi James[2], Getabu Albert[1], Gichana Moraa Zipporah[1]

[1]Department of Aquatic and Fishery Sciences, Kisii University, P.O. BOX 408-40200, Kisii, Kenya.
[2]Kenya Marine and Fisheries Research Institute, P.O. BOX 81651-80100, Mombasa, Kenya.

*Corresponding author email: carolynekerry09@gmail.com

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Abstract

An increase in the water level occurred in the Lake Naivasha leading to its merging with Lake Oloiden. The presence of Nile tilapia that is exploited commercially in the Lake Oloiden post water level rise is important. Study's main focus was to investigate the feeding selectivity of *Oreochromis niloticus* post water level raise in the Lakes Oloiden and Naivasha. The lake depth and secchi depth were measured and Nile tilapia was sampled monthly for one year and analysis (300 fish) was done for the feeding selectivity of *O. niloticus*. The food items that were present in the gut of fish in both lakes were: algae, detritus, other plant material, fish parts and zooplankton. An ontogenic shift was seen; juvenile fish consumed a higher percentage of zooplankton as compared to adult fish. The insects were not part of the fish's diet as previous (before water level rise) in the Lake Naivasha. Nile tilapia feeds during the day and food selection was affected by seasonality. The fish in both lakes were in a good condition and the fullness index and the vacuity index varied; although, no variation was noted with sex nor maturity stage. Nile tilapia diversified its diet and took advantage of new environment (Lake Oloiden). The fish in the Lake Oloiden have similar feeding selectivity with those in Lake Naivasha. Further research should be done on feeding selectivity of small sized fish.

Key words: Condition factor, Fullness index, Increased water level, Vacuity index

1.0 INTRODUCTION

Nile Tilapia (*Oreochromis niloticus*), a relatively large cichlid of African origin that was introduced and it's exploited commercially in the Lake Naivasha (Otieno *et al*., 2014a). It's a dominant species as compared to other tilapines: due to its high fecundity and fast growth rate. The Lake Naivasha and Lake Oloiden merged due to increased water level; attributed to increased rainfall due to climate change (Ballot *et al*., 2009). The presence of *Oreochromis niloticus* that are exploited commercially in the Lake Oloiden; post water level rise is of importance.

Oreochromis niloticus is an important fish in the ecology of tropics with its diet including; insect parts, detritus, grains, diatoms, zooplankton and algae (mainly consumed) (Otieno *et al*., 2014a; Abdulhakim *et al*., 2015). An ontogenic shift develops as it grows. Its' juvenile feed more on zooplankton because it's easier to digest and it meets their higher protein mass demand: having a high specific growth rate and metabolism. The fish's food item changes to phytoplankton and other plant material due to the development of the digestive juices: able to break the plant cell wall (Otieno *et al*., 2014a).

A fish's condition factor is an indicator of its well-being: index displays a result of an interaction between biotic and abiotic factors to the physiological condition of fish (Otieno *et al*., 2014b). The fullness index is a measure of ingested food (Ouakka *et al*., 2017). The degree of stomach repletion may be linked to fish's physiological requirements for growth: although, feeding intensity may vary due to food availability (Otieno *et al*., 2014a; Ouakka *et al*., 2017). Changes in the ecology may have occurred due to the increased water level which may influence feeding selectivity of fish. The aim of the study was to investigate the feeding selectivity of *Oreochromis niloticus* in the Lakes Oloiden and Naivasha post water level raise. This information is important for aquatic managers since O. niloticus is a link between the lower and upper trophic levels.

2.0 MATERIALS AND METHODS

2.1 Study area

The study was carried out in the Lakes Oloiden (00^{o}50'S, 36^{o}17'E) and Naivasha (00^{o}46'S, 36^{o}22'E). Seven sampling points were chosen in both lakes using Global Positioning System (GPS): Oloiden ST1, Oloiden ST2, Oseria, Midlake, Malewa, Korongo and Crescent (Figure 1).

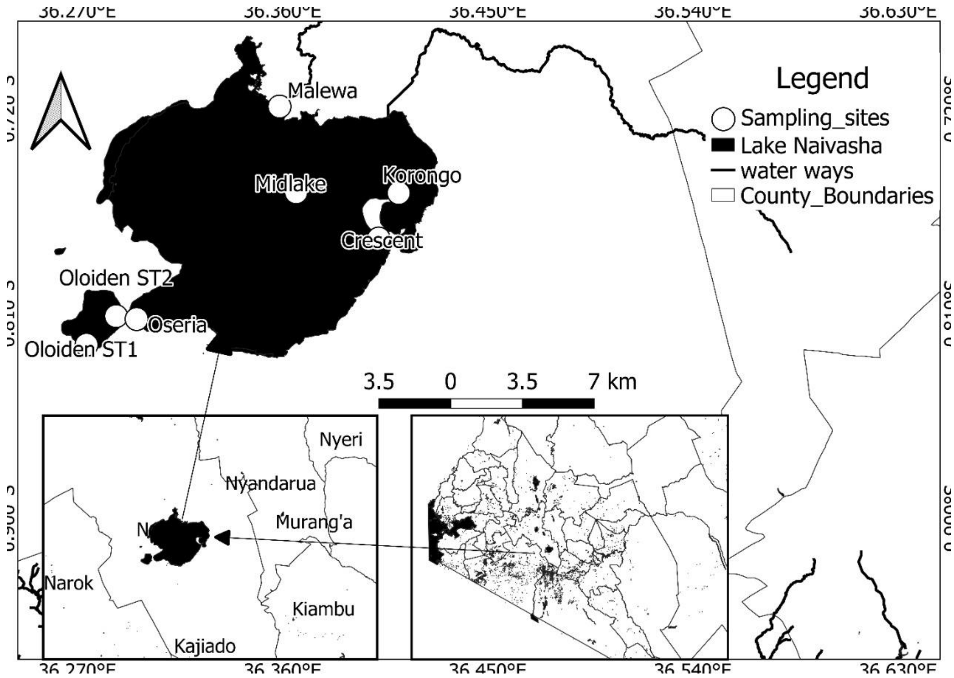

Figure 1. The study area map, showing the Lakes Oloiden (Oloiden ST1 and ST2) and Naivasha (Oseria, Crescent, Midlake, Malewa and Korongo) (Openstreetmap.org, 2021).

2.2 Sampling procedure and analysis

Sampling (fish and physical parameters) was done monthly for one year (August, 2020 to July, 2021).

2.2.1 Physical variables

The water depth and secchi depth were measured (Obegi *et al.*, 2021; Nyangau, 2021).

2.2.2 Fish sampling and analysis

The gill nets (1.78-6 inches) were cast for 4 hours during the day each month and site. A 24 hours sampling was done to establish when the Nile tilapia feds and the gill nets were lifted every four hours. Once the fish nets were retrieved from the water, length and weight were measured to the nearest centimeter and gram respectively. A total of 300 samples were analyzed from all sites and the maturity stages were identified (Belv'eze, 1984). The Nile tilapia specimens were dissected and gut samples were collected into labeled plastic vials and preserved in 4% formalin.

In the laboratory the stomach content was analyzed using modified point method (Hynes, 1950; Hyslop, 1980). They were weighed using an analytical balance to the nearest 0.1g. Stomach fullness (SF) or fullness index (FI) was expressed in percentage.

$$SF = \frac{SC}{W} * 100$$

Where; Sc is stomach content weight and W is the fish weight (Hureaus, 1969).

The stomach content was emptied into a petri dish, observation and analysis were done (under a compound microscope, ×100) and the food items were identified into categories. The categories were given points proportional to the approximate composition estimated, importance of each food category was expressed as a percentage.

The vacuity index (VI) is the percentage of empty stomachs with respect to all the stomachs that were examined (Hureaus, 1969).

$$VI = \frac{ES}{TS} * 100$$

Where; ES is the empty stomachs while TS is the total number of stomachs examined. Nile tilapia's condition factor (K) was calculated using Fulton's formulae.

$$K = \frac{W}{L^3} * 100$$

Where; W= fish weight and L= fish length (Fulton, 1911).

2.2.3 Statistical analysis

The diet was analyzed using Analysis of Variance (one-way) in Statistical Package for Social Scientists and the Tukey test was used in determination of the significant differences.

3.0 RESULTS

3.1 Depth and secchi depth

The depth and secchi depth were significantly different between the lakes ($P<0.05$) Lake Naivasha had an average depth of 7.7±3.8m and a Secchi depth of 0.6±0.1m. The Lake Oloiden's average depth was 6.6±1.2m while its average secchi depth was 0.5±0.1m.

3.2 Overall contribution

Its diet was largely composed of algae (61.6±17.4%) (**Figure 2**). The fish parts (14±5.2%) found in the gut were scales and fish eggs. The zooplankton contributed 12.9±5.8%, while detritus and other plant contributed; 23.1±14.4% and 16.6±12.4% respectively and debris' contribution was 14.7±7.4%.

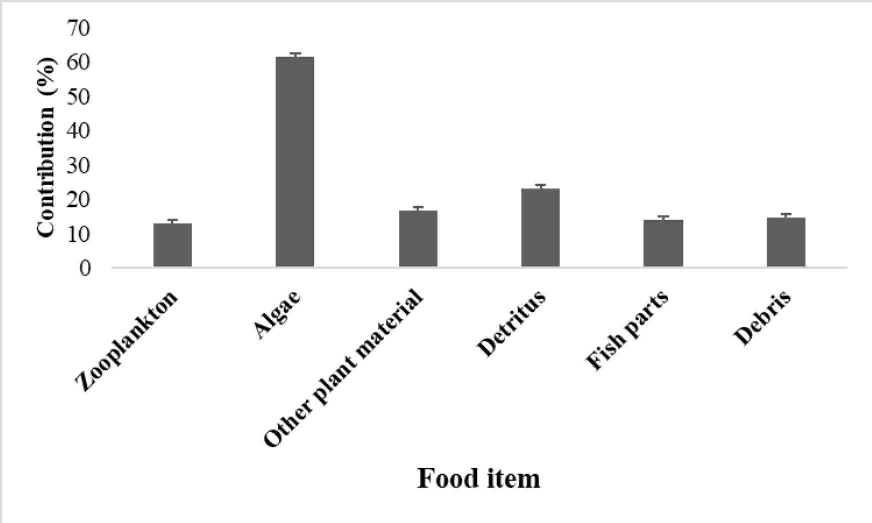

Figure 2. Contribution of various food items in the diet of *Oreochromis niloticus* in the Lakes Naivasha and Oloiden.

The fish mainly fed on algae, other plant material, detritus and zooplankton (significantly different between the lakes, P<0.05) (**Figure 3**). Lake Naivasha's Nile tilapia consumed fish parts.

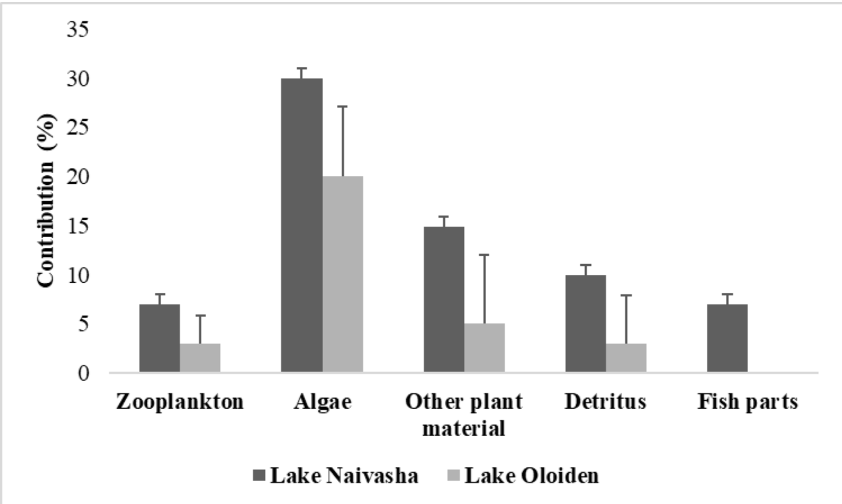

Figure *3*. Contribution of the food items in the diet of *Oreochromis niloticus* of Lakes Naivasha and Oloiden.

3.3 Ontogenic shift

The zooplankton, algae, detritus, fish parts and debris were similarly present in the gut of all the length classes (P>0.05). The other plant materials were significantly different in the length classes (P<0.05). Debris were also present in gut content of fish lengths that were >16cm. Algae constituted the highest percentage in all the length classes. The fish of 0-5cm (smallest total length) gut was largely dominated by algae. The younger fish consumed zooplankton but their consumption decreased as the fish length increased (**Figure 4**). Fish parts were consumed only by adult fish of TL (>16) cm.

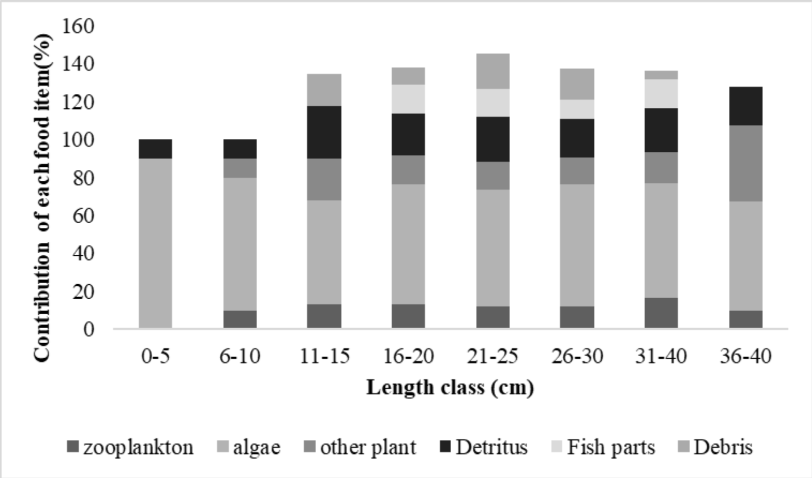

Figure 4. Ontogenic shift in feeding of *Oreochromis niloticus* (Lakes Naivasha and Oloiden)

3.4 Spatial contribution

Nile tilapia in the Lake Naivasha and Lake Oloiden fed on algae and detritus (significantly different, P<0.05). The fish that consumed fish parts belonged: Crescent, Korongo and Malewa (**Table 1**). Zooplankton percentage present in the gut were similar in all the sites. Present in the gut were debris.

Table 1. Contribution of food items in the diet of *Oreochromis niloticus* in the different sites (Lakes Naivasha and Oloiden).

Diet (% cont) Sampling site	Zooplankton	Algae	Other plant	Detritus	Fish parts	Debris
Lake Naivasha						
Oseria	13.2±5.7a	68.9±16.3a	15.5±14.7a	15.6±8.4a		10.0±5a
Crescent	12.9±6.5a	65.5±10a	13.7±6a	18.7±9.6a	10.0a	
Korongo	13.6±6.2a	68.6±13.2a	17.8±17.2a	20.0±9.5a	15.0±5.8a	17.9±5.7a
Midlake	14.3±5.3a	67.8±8.2a	10.0a	18±7.9a		
Malewa	12.9±5.4a	58.7±11.3ab	16.7±6.5a	19.4±5.4a	14±5.5a	
Lake Oloiden						
Oloiden ST1	9.5±1.6a	48.9±1.9b	16.4±10.5a	36.3±16.1b		20.0a
Oloiden ST2	12.5±4.5a	49.0±22b	22.8±17.2a	32.8±20.16b		16.3±11.1a

3.4 Diet and seasonality

Zooplankton, algae, other plant material and detritus were consumed in all the seasons. Seasonally: the fish parts, zooplankton and debris had no significant differences (P>0.05). The algae and detritus had significant difference (P<0.05); although similar in the short dry and the long rain season. The algae were distinct in the long dry and the short rainy season while for detritus the two seasons were similar (**Figure 5**). Fish parts were not part of

Nile tilapia diet in the short rainy season. The debris were not present in the fish gut during the long dry season.

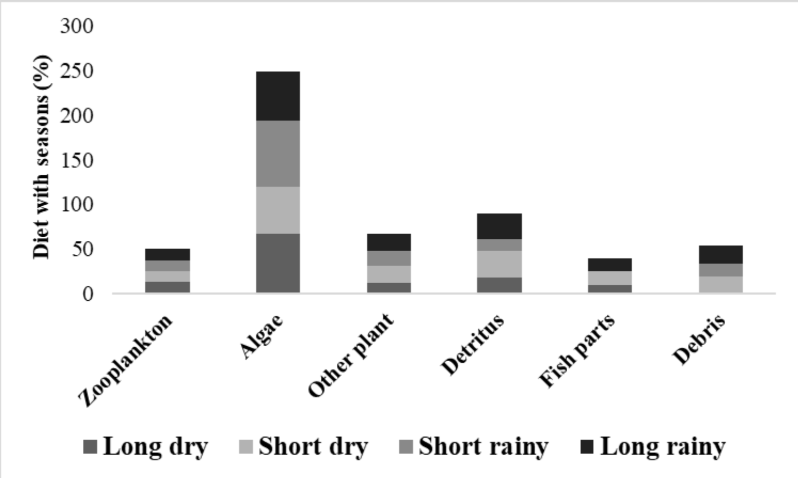

Figure 5**.** The diet in the Lakes Oloiden and Naivasha in various seasons.

3.5 Diel feeding rhythm

The highest peak of the feeding was at 12.00pm (3.85g) and at 4.00pm (3.6g). During the day the food intake could increase steadily n decrease after reaching the peaks. A decrease was noted at dusk to the lowest (12.00am) and increasing once its dawn (8.00am, **Figure 6**).

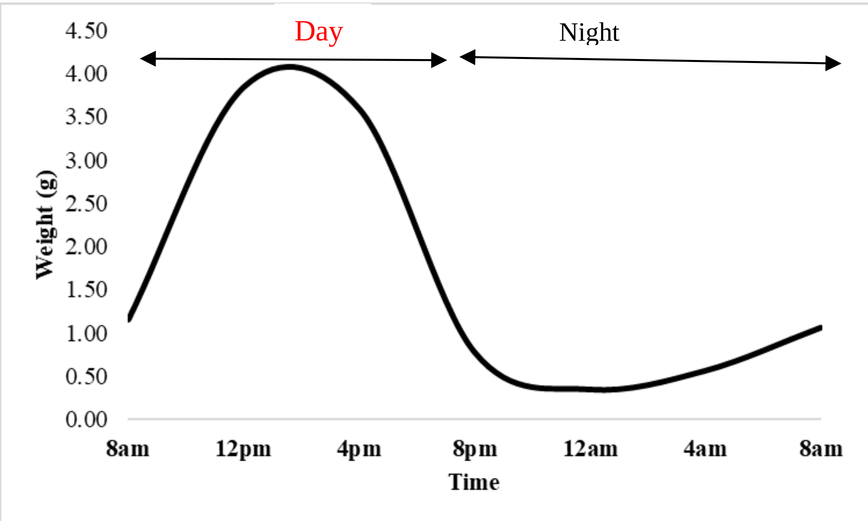

Figure 6**.** Diel feeding for *Oreochromis niloticus* in Lake Naivasha.

3.6 Condition factor, fullness index and vacuity index

The condition factor (K) did not vary with the months nor male and female (P>0.05) (**Figure 7**). The Lake Naivasha's condition factor was 1.9±0.2 while the Lake Oloiden's was 1.9±0.4 (not significantly different (P>0.05)). There was a significant difference in FI with months (P<0.05). The lowest being in the month of September and the highest was in June. The fullness index for female and male in the Lakes Oloiden and Naivasha were not significantly different, (P>0.05). Condition factor and the fullness index were similar in all the study sites (P>0.05).

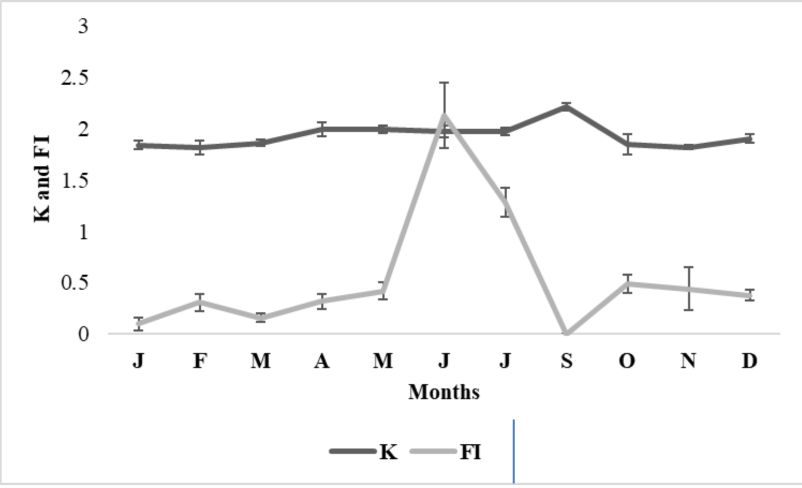

Figure 7. The condition factor (K) and fullness index (FI) of *Oreochromis niloticus* in the Lakes Naivasha and Oloiden.

The condition factor varied with the seasons (P<0.05): the long dry and short dry seasons were distinct while the long rainy and short rainy seasons were similar (**Figure 8**). The fullness index was significant difference in the respective seasons (P<0.05): the long dry was the highest while the short dry season was the lowest.

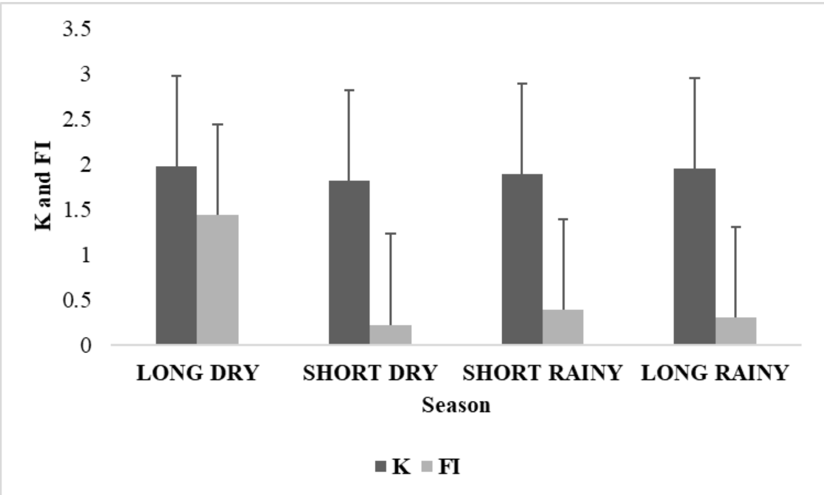

Figure 8. Seasonal variation of the condition factor (K) and fullness index (FI) of *Oreochromis niloticus* for the Lake Naivasha and Lake Oloiden.

The condition factor and the fullness index for the respective length classes were not significantly different (P>0.05) (**Figure 9**).

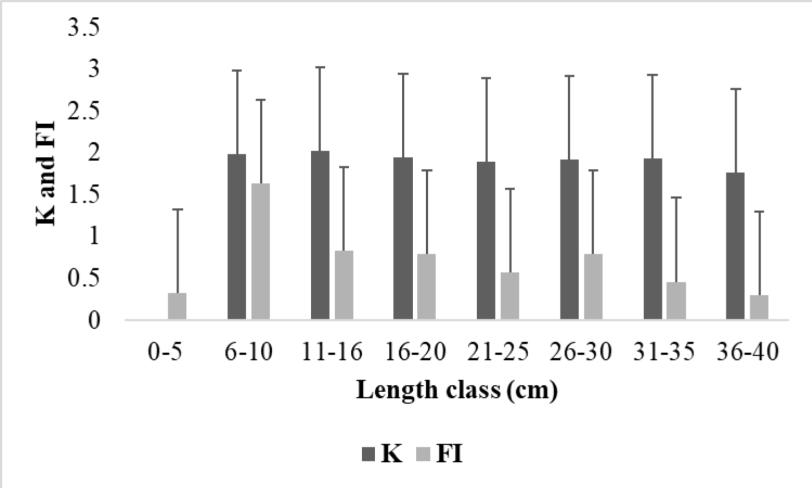

Figure 9. The condition factor and fullness index of *Oreochromis niloticus* in the various length classes.

The fullness index and the condition factor of the different maturity stages did not vary (P>0.05) (**Figure 10**).

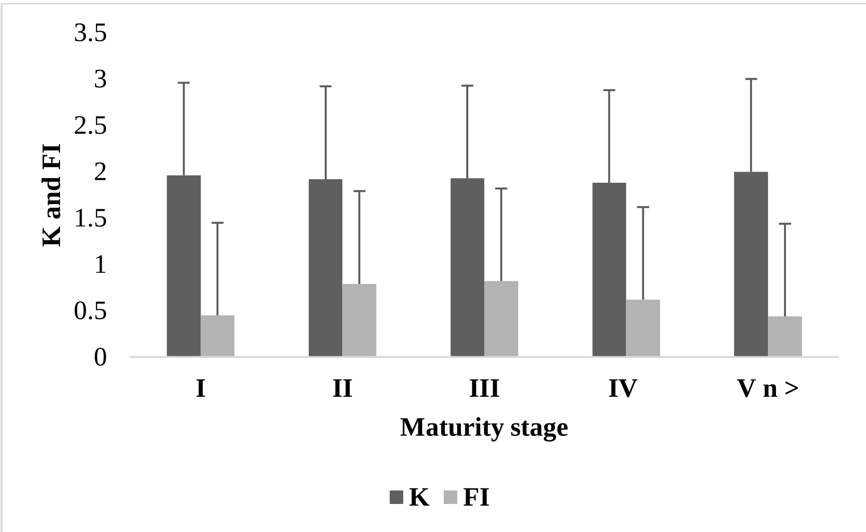

Figure 10. The condition factor (K) and fullness index (FI) for *Oreochromis niloticus* in the respective maturity stages (Lakes Oloiden and Naivasha).

The vacuity index was significantly different with the months (P<0.05, **Figure 11**) with the peak months being in March (2021) and August (2020) and not significant difference between sexes. The vacuity index was significantly different in the various study sites and the length classes (P<0.05). The vacuity index was not significantly different with the different maturity stages (P>0.05). The vacuity index had significant differences between Lake Oloiden and Lake Naivasha and with seasons (P<0.05). The highest VI was the short rainy and the lowest the short dry period.

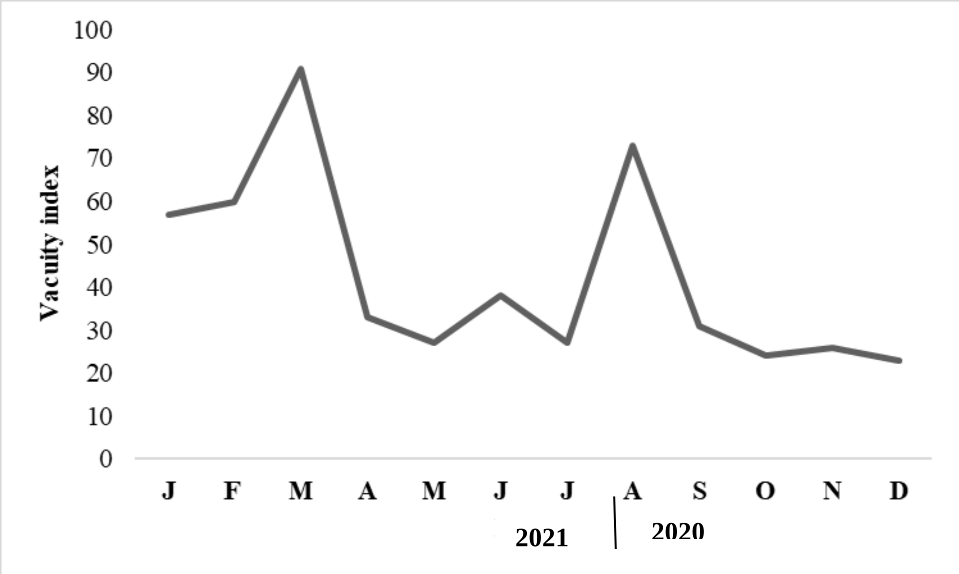

Figure 11. The vacuity index of *Oreochromis niloticus* (Lakes Oloiden and Naivasha).

4.0 DISCUSSION

The lake depth has increased post increase in the water level (it used to be 4-6m and 3-5m in the Lake Naivasha and Lake Oloiden respectively) (Hubble and Harper, 2002; Mavuti and Harper, 2005). The secchi depth has also increased which may be beneficial for aquatic flora (photosynthetic) and O. niloticus (use visual aid in feeding) (Obegi *et al*., 2021).

Algae was largely consumed since O. niloticus is herbivorous (feeds mostly on phytoplankton) (Njiru *et al*., 2004; Abdulhakim *et al*., 2015). It diversified its diet to include; detritus, fish parts, other plant material and zooplankton. Debris (mud and sand) were found in fish from Korongo, Oseria (fish breeding sites), and Oloiden ST1, ST2 and the fish whose TL was >16cm (indicating younger fish don't feed from bottom). Nile tilapia could be a benthic feeder (Abdulhakim *et al*., 2015). Observed was the absence of debris in the long dry season which means the fish may not have fed from the bottom in that period.

Nile tilapia feeds during the day: its needs visual aid (Otieno *et al*., 2004a). It feeds more around midday and before dusk. The lowest stomach content was recorded at midnight and may be attributed to completion of digestion of food intake just before dusk (Njiru *et al*., 2004; Otieno *et al*., 2014a). The fish of the smallest total length (0-5cm) did not have zooplankton in their gut content in contrast to the previous findings: Njiru *et al*., 2004; Outa *et al*., 2014a. On the contrary, the fish of 0-5cm had a high abundance of phytoplankton (Njiru *et al*., 2004). Although there may have been bias since there were few fish samples that were obtained. Zooplankton considerably contributed to the diet composition of fish (6-20cm, TL); its consumption satisfies their high specific metabolic rate (Otieno *et al*., 2014a).

A low % presence of zooplankton was noted in fish of 31-35cm, TL; which agrees with Otieno *et al*., 2014a findings.

The zooplankton, detritus, algae and other plant materials were consumed in all the seasons. The presence of *Acacia xanthophloe* diversified the ecosystem and food presence in the Lakes Naivasha and Oloiden. In the Lake Oloiden, second to algae in abundance was detritus which was attributed to the presence of acacia which fell in the water due to the increase in the water level. It Increased decaying matter which was of ecological significance: since O. niloticus adapts and exploits niches available; reducing niche competition (Njiru *et al*., 2004). The fish parts present in the gut were: scales and fish eggs; present only in Lake Naivasha's fish breeding sites (Crescent, Korongo, Malewa). There was a possibility of ingesting eggs during feeding (O. niloticus is a mouth brooder) (Njiru *et al*., 2004). There were no insects eaten by Nile tilapia and it could be due to lessening of edge macrophytes due to increased water level, contrary to Otieno *et al*., 2014a; Njiru *et al*., 2004.

The Nile tilapia had a good condition factor (>1) in both lakes. This could be attributed to available food and good water quality (physical-chemical parameters within fish's tolerable ranges i.e., temperature, pH and oxygen) (Otieno *et al*., 2014a). The condition factor did not vary with months, sexes, maturity stages, length classes and the study sites sampled. It was similar in Lake Oloiden and Lake Naivasha showing a good adaptability of fish to the environment. The findings that both sexes and all maturity stages had a similar K contrasted with previous studies (Otieno *et al*., 2014b). There was a difference with seasons: long dry and short dry were distinct while long rainy and short rainy season were similar. The seasonality may have an effect on the ecosystem which in turn affects fish well-being.

The fullness index was high in May, June (long rainy season) and July this may be due to availability of food then and the preceding months. Noted was a seasonal rhythm of food which may tally with fullness index (Ouakka *et al*., 2017). It did not vary with sex, maturity stages, lakes (Lake Naivasha and Lake Oloiden), length classes and sites sampled. There was variation with months, an indicator that seasonality had an effect in feeding of fish (Ouakka *et al*., 2017). The fullness index was different in the respective seasons, it was highest in the long dry; which was attributed to higher temperature and food availability. Male and female Nile tilapia had a similar fullness index; sex may not have an effect on fish feeding (Ouakka *et al*., 2017). The fish in all maturity stages and sizes had a similar fullness index; fish of all sizes and stages feed at same rate contrary to Abdulhakim *et al*., 2015 and Ouakka *et al*., 2017.

The degree of stomach repletion may be indicative of trophic environmental condition. The vacuity index varied with the length class, months, seasons, lakes and study sites. Fish in the same lake or the different study sites may face different ecological conditions that have an effect on their physiological functioning. It didn't vary with sex and maturity stages. The vacuity index was highest in short rainy and lowest in the long dry season; variation could be change in food availability (seasons may impact fish). The vacuity index changes with the length classes; different sizes may have different needs (Ouakka *et al*., 2017).

5.0 CONCLUSION

Nile tilapia exploits more than one type of food, it excluded insects post water level rise and adapts to the new environment (Lake Oloiden). The fish in the Lake Oloiden had similar feeding selectivity with those in Lake Naivasha. Further research should be conducted on feeding selectivity of small sized fish.

6.0 ACKNOWLEDGEMENT

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