A CONSOLIDATED TECHNICAL REPORT FOR ATAAS PROJECT 3

Fish feeding interactions and the potential for fisheries productivity in lakes George and Edward, western Uganda.

Compiled and produced by: Mwebaza-Ndawula, L.

Contributing scientists: Bwanika, G., Wandera S. B., Kiggundu, V., Pabire Gandhi, W., Magezi, Namulemo, G ., Nsega, M., Sekiranda, S., Musubika, S. & Owori Wadunde, A.

February, 2014

TABLE OF CONTENTS

Executive summary……...3

Background……...5

Common natural fish food organisms…….5

Materials and Methods…….7

Results and discussion……...9

Physico-chemical environment of Lake Edward……9

Algal community in the environment……..9

Algae in the diet of commercial fishes……12

Zooplankton in the environment……12

Zooplankton in diets of commercial fishes……....13

Macro-benthos community in the environment……14

Macro-benthos in diets of commercial fishes ……...15

Diet changes with size of *Bagrus docmac* in Lake George……..17

Diet changes with size of *Bagrus docmac* in Lake Edward…….18

Diet changes with size of *Clarias gariepinus* in Lake Edward ……...18

Diet changes with size of *Oreochromis niloticus* in Lake George……. 19

Diet changes with size of *Oreochromis niloticus* in Lake Edward…….20

Energy densities……..20

Conclusions…….23

Recommendations …….24

References……..25

1.0 EXECUTIVE SUMMARY

Lakes George and Edward are small water bodies located in the western arm of the East African Rift Valley. Lake George is a small (250 km^2) shallow water (mean depth 2.5 metre) system and is wholly located in Uganda. Lake Edward is much larger (2325 km^2), deeper water body with an average depth of 34 metres and maximum depth of 112 metres (UNDF, 2013) and is shared between Uganda (29%) and DR Congo (71%) (Beadle, 1966). Both lakes are drained by several rivers and streams from the Rwenzori Mountains and from the rich agricultural areas to the north east. The two lakes are linked with each other by a 40km long Kazinga Channel. The lakes harbor a number of fish species of which three, the Nile tilapia, *Oreochromis niloticus*, the African catfish, *Clarias gariepinus* and the Semutundu, *Bagrus docmac* were the subject of this study. The objective of the study was to investigate the natural feeding interactions between key commercial fish species and the available natural food sources, namely the algae, zooplankton, macro-benthos and prey fishes and establish the potential of the two lake environments and the food resources therein to sustain high fish productivity.

A prominent feature of the two lakes was domination by high algal biomass (especially Lake George, up to 95% of the total biomass) and this constituted a major natural food source for the fish and other communities. Other natural fish foods included the zooplankton constituted by copepods, cladocerans and rotifers. Zooplankton communities were dominated by one cyclopoid species, *Thermocyclops hyalinus* (*neglectus*) exhibiting lake-wide distribution. Estimated total zooplankton abundances of >130,000 ind. m^{-2} were considered to be sufficient for nutritional support of fisheries. The macro-benthic community was dominated by insects of which the midgefly larvae (chaoborids and chironomids) constituted the bulk and were prominent natural food constituents especially in Lake Edward. Molluscs were nearly non-existent in Lake George and rare in Lake Edward save for one species, *Melanoides tuberculata*. Most macro-benthos types generally occured lake-wide and estimated abundances of > 1000 ind. m^{-2} were considered to be sufficient for nutritional support of fisheries.

The diet of *O. niloticus* in Lake George was based on the superabundant algae of the lake (95% of total biomass). 89% of the diet was blue green algae while 11% was constituted by green algae. On the other hand, the diet of the same species in Lake Edward was more diverse, with bulk contributions from algal sources i.e. diatoms and blue-green algae (37% and 31% respectively) supplemented by detritus, zooplankton, insect remains and green algae in that order.

Zooplankton , although rich in diversity and abundance in the two lake environments, were minimally utilized by the three commercial fishes under study, only contributing a paltry 10% to the diet if *O. niloticus*. It was however noted that larval and juvenile fishes (<10 cm TL) were missing in the study samples obtained and from purely theoretical considerations, it is suspected that some of these small size fish categories could as well be ingesting zooplankton food sources.

The bulk of the diet of *B. docmac* in Lake Edward was constituted by fish and fish remains (56%) and the abundant insects (44%) with haplochromines and midge fly larvae as the main contributors respectively. The same species in Lake George ingested a similar diet although

insects contributed minor proportions. The diet of the African catfish, *Clarias gariepinus* in Lake Edward was constituted by the abundant insects with the bulk from *Chaoborus* (59%). Others were chironomids, Odonata and unidentified insect remains. Supplementary food items were haplochromines unidentified fish remains and higher plant materials. There is evidence of greater utilization of the more abundant food items in the environments of the two lakes.

Within the size range of *B. docmac* from Lake George (11->50 cm TL), the diet (i.e. fish and insects) did not show changes within different size classes. However the same species from Lake Edward, smaller fishes up to 35 cm TL ingested a mixture of fish and insects, thereafter switching to an all-fish diet. In *C. gariepinus* from Lake Edward, the diet of fish up to 25 cm TL was composed of only insects. Beyond this size, a mixture of insects and haplochromine fish prey was utilized.

Two size classes (11-15 & 16-20 cm TL) of *O.niloticus* in Lake George consumed nearly similar proportions of blue green and green algae. However, in Lake Edward, comparable size classes the same fish species consumed similar proportions constituted by blue-green algae, diatoms, green algae, zooplankton, detritus and insect remains.

In Lake Edward, mean gross energy per unit gram of *C. gariepinus* was not significantly different from energy densities of *B. docmac* ($P = 0.965$). *O. niloticus* and Haplochromines had much lower energy densities than both *C. gariepinus* and *B. docmac*. Energy densities among fish species in Lake George followed a similar trend as in Lake Edward. A comparison of energy densities of fishes between the two lakes revealed significantly higher energy densities for all fish species in Lake Edward than in Lake George. These preliminary findings indicated that *B. dockmac* and *C. gariepinus* confer the same energy per gram of fish tissue. The two species were also found to yield more energy per gram as when compared to *O. niloticus* and haplochromines. It was noted that overall, fishes from Lake Edward yield more energy than their counter parts from Lake George. It is thus concluded that the dietary sources in Lake Edward (i.e. abundant insects and haplochromines) and prevailing conditions in general, evidently favour a better performance of the studied commercial fishes compared to the same fishes in Lake George with mostly algal food sources.

2.0 BACKGROUND

Feeding interactions relate to the choice, acceptance and subsequent ingestion of available food materials in the environment by organisms. In wild fish populations, the physical environment is the water where the fish lives and the food environment includes all the aquatic living organisms, both plants and animals. In addition there is also the non-living part of the environment such as the decaying remnants of plans and animals or detritus which may also be consumed either intentionally by some fishes but in some cases is fortuitously or accidentally consumed in the cource of ingesting targeted food organisms. For example many fishes, which forage for live prey organisms in the bottom sediments often unintentionally take in nutritionally rich detrital materials that may serve as important food supplements.

2.1 Common natural fish food organisms and their utilisation by fish

For fishes in natural water bodies (lakes, reservoirs, dams, rivers/streams, swamps/marshes, ponds) the natural live foods include, algae or phytoplankton, micro-invertebrates (mainly zooplankton and protozoa), macro-invertebrates or macro-benthos and small fishes.

Some fishes feed on algae as the preferred food resource. Such fishes include the Nile tilapia or Ngege (*Oreochromis niloticus*) and a host of haplochromine (Nkejje) fishes. Other fishes specialize in feeding on zooplankton (tiny microscopic organisms living in the water mass or water column) characterised by lack of a backbone). A common example is Mukene (*Rastrineobola argentea*) and a number of Nkejje species. In addition and more important is the fact that all fish babies or fish larvae of all fishes feed on selected members of zooplankton as the first external food after absorption of the yolk sac. As such, the zooplankton represents the equivalent of baby milk in mammals and constitutes a natural starter food responsible for survival at a very delicate and vulnerable stage of fish development.

A number of fishes both juveniles and adults feed on selected macro-invertebrates most of which are picked from the surface of bottom sediments. Examples in this category include the Nile perch (*Lates niloticus*) whose juveniles and sub-adults derive a large proportion of their food from *Caridina nilotica* or freshwater shrimp that, to a great extent, is associated with the bottom sediment habitat. Others actively search for live food items such as worms and chironomid larvae buried in bottom sediments. One example is the Ningu or L*abeo victorianus*. Many freshwater snails are also commonly picked on the surface of sediments by a number of fishes including the lungfish or Mamba/Kamongo (*Protopterus aethiopicus*) and some haplochromine species. Another category of fish feed on other fishes. These fish predators are described as piscivorous and include the Nile perch, the African catfish or Male (*Clarias gariepinus*), and Semutundu (*Bagrus docmac*).

Food is among key environmental factors that determines the condition or wellbeing of the fish. Ingested food is used for metabolic maintenance, somatic or body growth and reproductive energy. Energy is of great importance as it explains not only the suitability of the energy source but also the environmental factors that may influence food availability, utilization and subsequently fish growth. The latter is the ultimate controller of sustainable production in fish production systems.

The objectives of the study were to: determine occurrence, diversity, distribution and abundance patterns of key fish food organisms (algae, zooplankton, macro-benthos and prey fishes) in lakes George and Edward (Fig.1) in relation to their utilization by three selected commercial fishes (the Nile Tilapia, *Oreochromis niloticus,* Semutundu, *Bagrus docmac* and the African catfish, *Clarias gariepinus)* and energy densities derived thereof. Key environmental parameters such as temperature, dissolved oxygen, pH, electrical conductivity and water transparency were concomitantly determined. Field, lake-wide data collections in lakes George and Edward (Fig. 1) were undertaken at various times between 2011 and 2012.

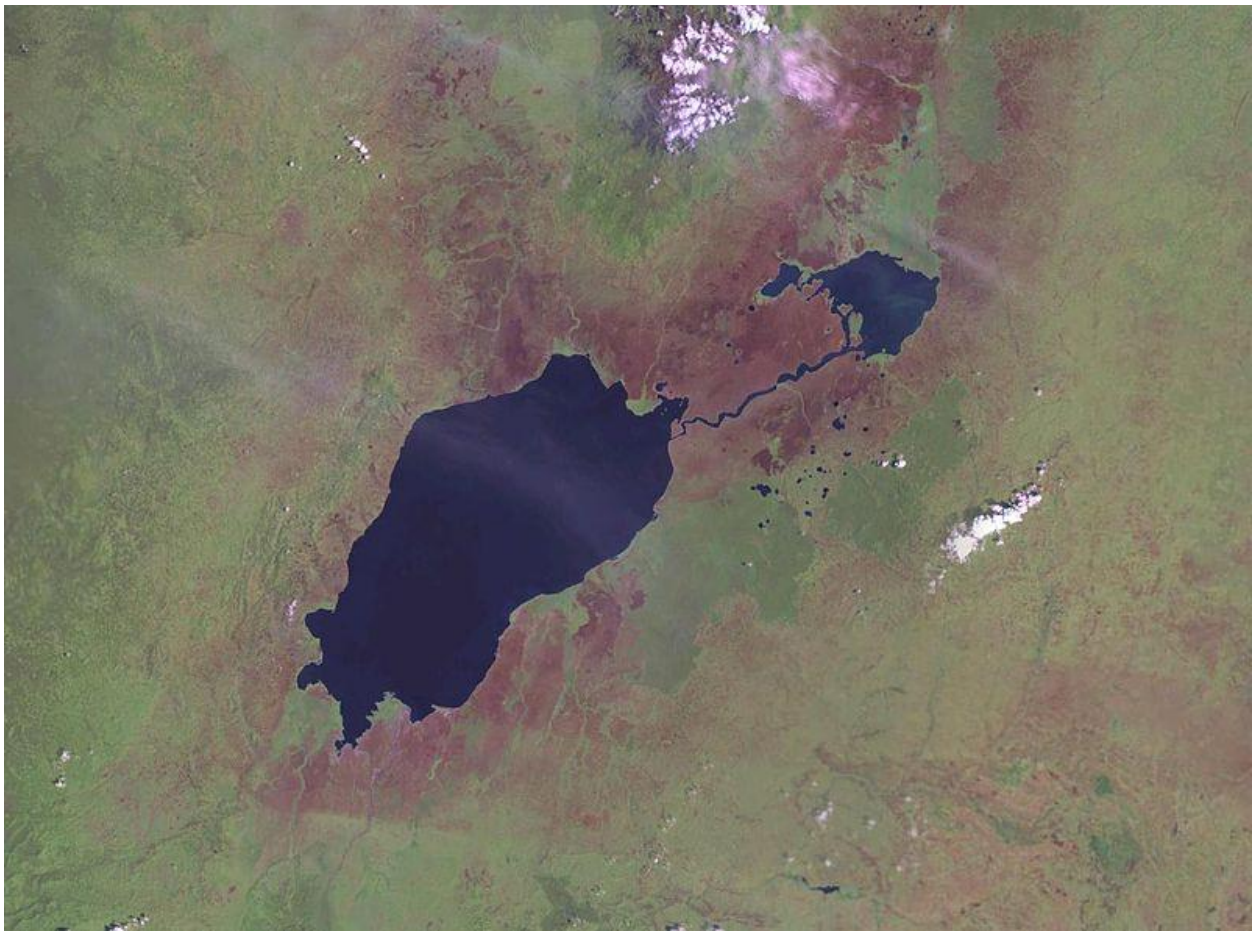


Figure 1. Satellite image of lakes George and Edward and the connecting Kazinga channel in the western Rift valley, Uganda.

3.0 MATERIALS AND METHODS

3.1 Algae and pyhsico-chemical parameters

Both lakes George and Edward were sampled for algae at depth of 0.5 m using a 2 L Van-Dorn water sampler and samples were placed in scintillation glass bottles and Lugol's solution added as a preservative. Analysis was done using an inverted microscope at appropriate magnification. Field sampling was done at inshore and offshore sites close to the historic reference stations sampled by Ganf (1974). Water temperatures, dissolved oxygen, pH and conductivity, turbidity profiles were measured using a submersible CTD 90 multiprobe (Sea & Sun Technology). Lake transparency was measured in the shade of the boat, using a 25-cm white disc.

3.2 Zooplankton

Zooplankton were sampled at selected inshore, offshore and river mouth sites by taking 3 replicate vertical hauls using conical plankton net of 60 µm mesh with 0.25 m mouth diameter. Freshly collected samples were placed in clean, labelled plastic bottles and preserved with 4% sugar formalin. Representative sub-samples (2, 2, 5 and 10 ml) were each placed in a plankton counting chamber and examined under an inverted microscope at X40 and x100 magnification for enumerating of individuals and species identification respectively. Identification was done using taxonomic manuals by (Boxshall & Braide 1991, Korovchinsky 1992, Rutner-Kolisko 1974, Koste 1978, and Korinek 1999) and members of each species were quantified to generate abundance data.

3.3 Macro-benthos

Macro-invertebrate samples were obtained from selected inshore offshore and river mouth sites using a Ponar grab with an opening of 238 cm^2. Triplicate grabs were taken from each sampling site. Samples were washed through a sieve of mesh size 0.4 mm, and samples preserved in 5 % formalin. Organisms were sorted and taxonomically identified under a dissecting microscope (x 400 magnification) using taxonomic keys by Mandahl-Barth, (1954); Merritt. and Cummins (1997, Pennak (1989).

3.4 Fish

Fish specimens were obtained from experimental fishing using graded mesh multifilament gillnets ranging from 1-8 inches. The nets were set overnight at selected sites covering diverse habitats on Lakes Edward and George. The catch was sorted into species following Greenwood (1966) and biometric data for each species taken as in LVFO (2007). Stomachs with food were preserved in 5% formaldehyde solution for laboratory analysis of the gut contents. Large and clear food items visible to the naked eye were sorted and identified; small and invisible items were examined using a binocular microscope (magnification x45) and compound microscope (magnification x400). Identification of food organisms was based on identification checklists by Pennak (1978), Mosille (1984), Fernando (2002), and John *et. al*. (2002). Percentage importance for the different food items was determined according to Standard Operating Procedures (LVO, 2007).

3.5 Energy densities

For generation of data on energy values, fish specimens were captured using experimental gillnets and supplemented by sub sampling fishermen's catch in lakes George and Edward. For each selected fish specimen, length (total length and standard length) to the nearest 0.1 cm and body mass to the nearest 0.1 g were recorded. Each specimen was dissected to remove the digestive tract. The fish minus the digestive tract was reweighed to the nearest 0.1 g. Small-sized fish were taken whole, while a section (a caudal section of the fish from the point at the end of the dorsal fin) of up to about 500g was taken from the medium and large-sized fish. Samples were transported under ice to the laboratory and oven-dried at 80^{o}C to constant dry weight (Meakins, 1974b). Each dry sample was milled using a coffee-mill grinder to powder form and freeze-stored at -20^{o}C in airtight bags.

Calorific energy equivalents were determined in duplicate/triplicate by combusting 0.5 - 1g milled sub samples in an Oxygen bomb calorimeter making record of initial and final temperature of the calorimeter water bath, fuse correction length (FC) and Nitric acid correction (AC) as outlined in Parr Instrument Company bomb calorimetry manuals. In order to express energy content on a dry matter basis and on an ash-free (organic matter) basis, additional data on percent organic matter (OM) was obtained by ashing approximately 1 g tissue sub- samples (in triplicate) using a micro furnace at temperatures of 400oC (raised at a rate of 100oC per 30 minutes). Once at 400oC, the sample was ashed for at least three hours, thereafter cooled in a desiccator and ash-free dry weight taken. Percent organic matter was therefore calculated as:

$$\%\ Organic\ matter = \left(\frac{Organic\ matter}{Dry\ matter} \right) x\, 100$$

To check for endothermy during bombing, due to presence of CaCO3 (Paine, 1966), benzoic acid was bombed in calibration runs and water equivalent (W) calculated as:

$$W = \frac{\left[(mass\ of\ \ benzoic\ acid\ \ in\ \ g)\, x\ \ (6318\ cal/g) + FC + AC \right]}{(T6 - T0)}$$

Where W = Water equivalent; T0 = Temperature at the beginning of the run; T6 = Temperature after 6 minutes; FC = Fuse Correction; AC = Nitric acid Correction.

Following these calculations:

Energy content (J) on a dry matter basis was calculated as:

$$\text{Energy content (J g-1 dry matter)} = \frac{\left[((T6 - T0)\, x\, W) - FC - AC \right] x\ 4.18^{*}}{(Sample\ mass\ as\ is)\, x\ DM}$$

Energy content (J) on ash-free or organic matter basis was calculated as:

$$\text{Energy content (J g-1 Ash-free dry mass)} = \frac{\left[((T6 - T0)\, x\, W) - FC - AC \right] x\ 4.18^{*}}{(Sample\ mass\ as\ is)\, x\ DM\ \ x\ OM}$$

*4.18 convert calories to joules

4.0 RESULTS AND DISCUSSION

4.1 Physical-chemical environment of Lake Edward

Lake Edward environment was characterized by high conductivity (mean values: 556.81-887.75 µS/cm) (Table 1) compared to other lakes in Uganda. Values of dissolved oxygen were strikingly low (mean values: 4.08-5.43 mg/L) although well above the critical value (2.5 mg/L) for productive freshwater habitats. Other parameters (temperature, pH and secchi depth) were normal and considered suitable for freshwater aquatic productivity.

Table 1. Selected physico-chemical parameters in Lake Edward

Field Site/Habitat	Electrical conductivity (µS/cm)	Dissolved oxygen (mg/L)	Temperature ^{0}C	pH	Secchi depth (m)
Kazinga channel offshore (8.7m)	887.75±0.16	4.9±0.34	26.30±0.02	8.84±0.02	1.54
Kazinga channel mouth (3.1m)	556.81±0.05	4.08±0.17	26.21±0.00		0.6
Katwe bay (2.3m)	602.27±0.09	5.43±0.05	26.78±0.05	9.16±0.03	0.5
Nyamugasani offshore (24m)	883.38±0.12	4.34±0.13	25.88±0.01	8.90±0.03	1.71
Nyamugasani mouth (3.4)	868.21±0.10	4.29±0.10	26.27±0.06	8.84±0.02	1.08

Other environmental variables (temperature, pH and dissolved oxygen) in both lakes were within suitable ranges for aquatic productivity.

4.2 Algal community in the environment

The algal community in lakes George and Edward was composed of five major groups: Blue-green, Green, Diatoms, Crysophytes, and Euglenophytes. Most field sites were dominated by blue-green algae constituting > 90% of the total algal biomass in Lake George (Fig. 2). In this lake, the algal composition and distribution patterns observed appear not to have changed much from reports by earlier workers (Rich, 1933; Beadle, 1965; Talling & Talling, 1965 and Ganf, 1974).

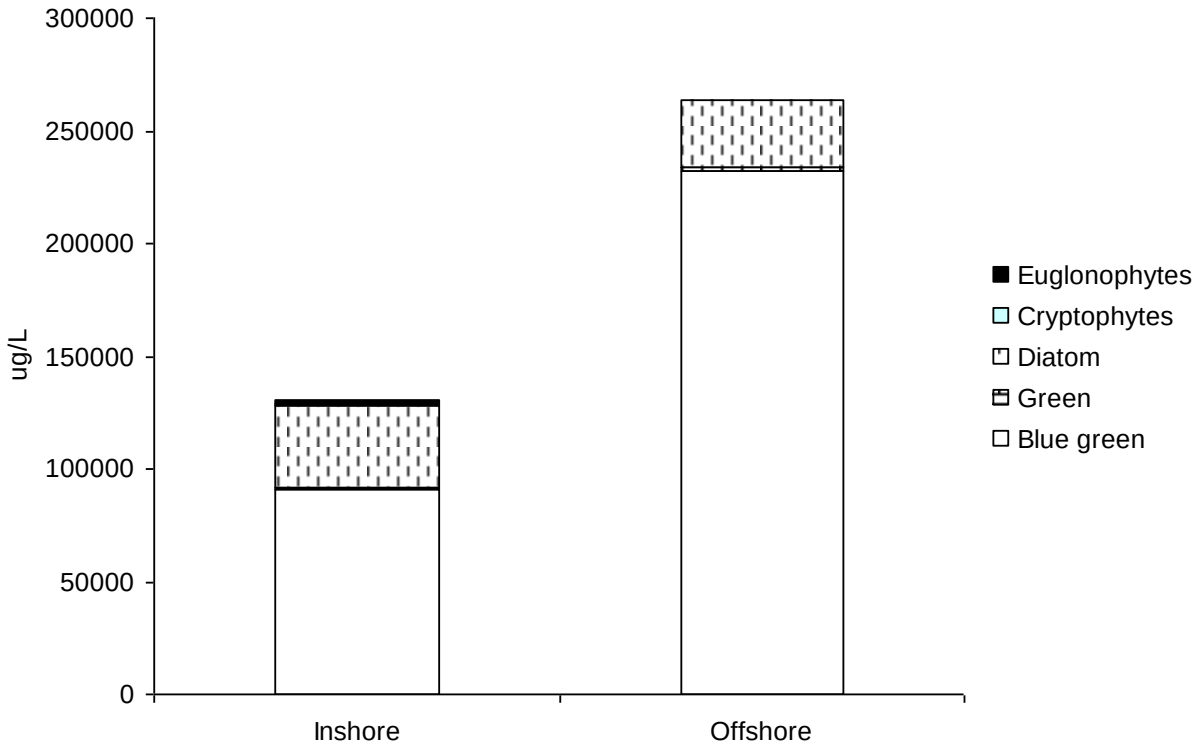


Figure 2. Algal biomass estimates for inshore and offshore habitats in Lake George

In the shallow Lake George algal biomass was higher around offshore (> 250,000 µg/L) than inshore (up to 140,000 µg/L) habitats (Fig. 2). This horizontal algal distribution pattern is in agreement with earlier records by Ganf (1974) who suggested a concentric pattern of water movement, resulting in maximum values occurring in the central areas of the lake. In the larger and deeper Lake Edward the opposite pattern of algal distribution was the case with higher biomass values offshore (up to 11, 000 µg/L) compared to inshore sites (ca.9000 µg/L). Comparison of the algal biomass estimates for the two lakes suggests that Lake George is more productive than Lake Edward. The occurrence of high algal biomass especially in Lake George (Fig. 2) is an indication of high nutrient concentrations in the lake (eutrophic; Vollenweider, 1968) although the quantified sources of the nutrients are not well known. Ganf (1974) argued that the 'large eutrophic phytoplankton crops' such as that in Lake George are likely to develop where catchment areas provide substantial quantities of nutrients which may be recycled many times within the lake. Nonetheless, for purposes of fisheries production and management, the observed high algal biomass can be considered to represent a dependable food resource for the algae-eating organisms such as the Nile tilapia (*Oreochromis niloticus*), other cichlid fishes and to some extent, aquatic invertebrates.

In Lake Edward, two groups of algae were also prominent beside blue green algae. These were diatoms with peak values at most offshore sites and cryptophytes at inshore sites (Fig.3).

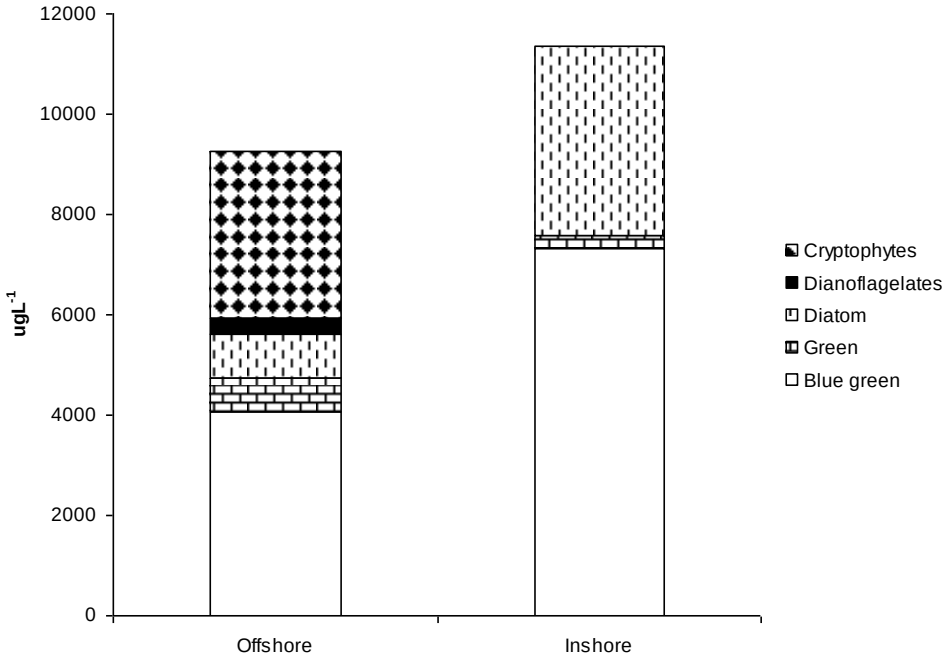


Figure 3. Algal biomass estimates for inshore and offshore habitats in Lake Edward

4.3 Algae in diets of commercial fishes

Of the three commercial fishes investigated (*B. docmac*, *C. gariepinus* and *O. niloticus*) only O. *niloticus* utilized algae as the preferred food source. The diet of *O. niloticus* In Lake George was constituted by the dominant algal sources in the lake, mainly blue-green algae (89%) and green algae (11%) (Fig. 4).

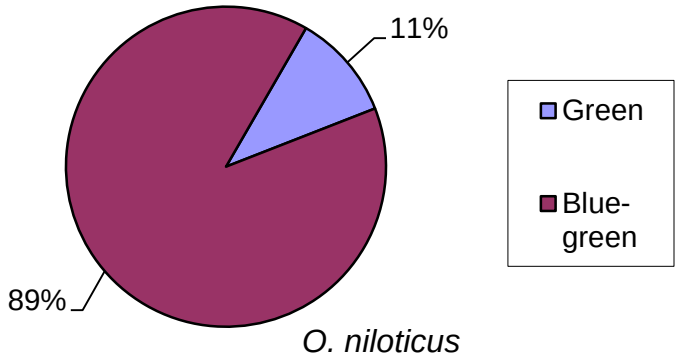


Figure 4. The diet of *O. niloticus* in Lake George (key to diet items: Blue-green=blue green algae; Green=green algae

The bulk of the diet of *O. niloticus* in Lake Edward was derived largely from the abundant algal community (71%), with blue-green algae as the main component followed by diatoms and green

algae in that order. Additional diet components were detritus, zooplankton, insect remains and green algae (Figure 5). This diet represents a sharp contrast from the diet of the same species in Lake George where a two-item diet was recorded (Fig. 4). This fish species therefore appeared to take advantage of the greater diversity of the available fish food organisms in Lake Edward compared to Lake George.

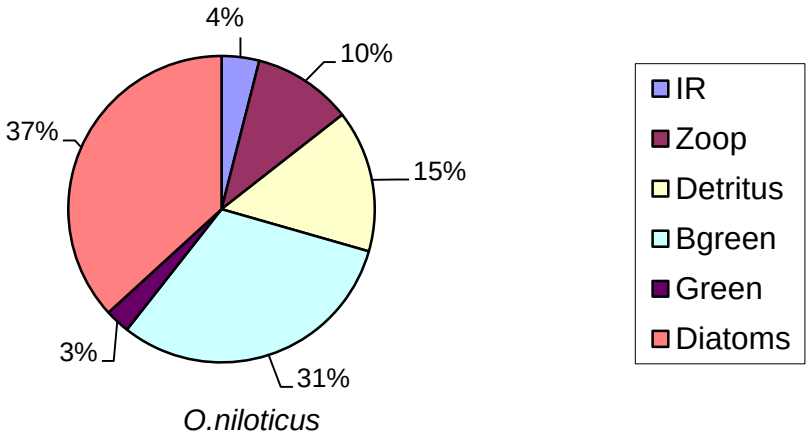


Figure 5. The diet of *Oreochromis niloticus* in Lake Edward (key to food items: IR= insect remains; Zoop= zooplankton; Bgreen=blue green algae).

Elsewhere, algae especially blue green algae have been reported to constitute a relatively high proportion of the Nile tilapia diet in crater lakes (Bwanika *et al*., 2004), in Victoria and Kyoga basin lakes (Nagayi-Yawe *et al*., 2006), Murchison bay and Lake Mburo (Semyalo *et al*., 2009) but not in Lake Victoria (Bwanika *et al*., 2006).

In terms of environmental quality for fishery management, the challenge in both lakes George and Edward is to ensure availability of sufficient algal biomass for fish nutrition while avoiding excess amounts, which if not taken up in the food chain, decompose and may cause high biological oxygen demand (BOD) that inherently interferes with aerobic life and productivity processes in the lake. The solution lies in control of influx of nutrients particularly those from point and non-point sources around the lake.

4.4 Zooplankton community in the environment

Zooplankton fish food organisms in the two lakes were constituted by three main groups: copepods, cladocerans (water fleas) and rotifers (wheel animalcules). These groups occurred widely in the two lakes. The communities in the two lakes were dominated both in inshore and offshore habitats by copepods. As reported by Burgis et al. (1973), the copepod community was made up of largely a single species, *Thermocyclops hyalinus* (=*neglectus*). There was a clear trend of total abundance with higher density estimates in offshore (pelagial) relative to inshore sites (Fig. 6). River mouth areas supported generally lower concentrations of zooplankton than both offshore and inshore habitats. Compared to other water bodies in Uganda where zooplankton community has been shown to drive lucrative pelagic fisheries (Mwebaza-Ndawula & Schiemer, 1997), Mwebaza-Ndawula 1998, Mwebaza-Ndawula *et al.* 2003) the density

estimates observed (i.e. > 100,000 ind. m^{-2} and up to 1,300,000 ind. m^{-2}) coupled with their lake-wide occurrence in both lakes, suggest potential to support larval fishes (including those of commercial species) and lucrative pelagic fisheries as is the case for Mukene in Lake Victoria.

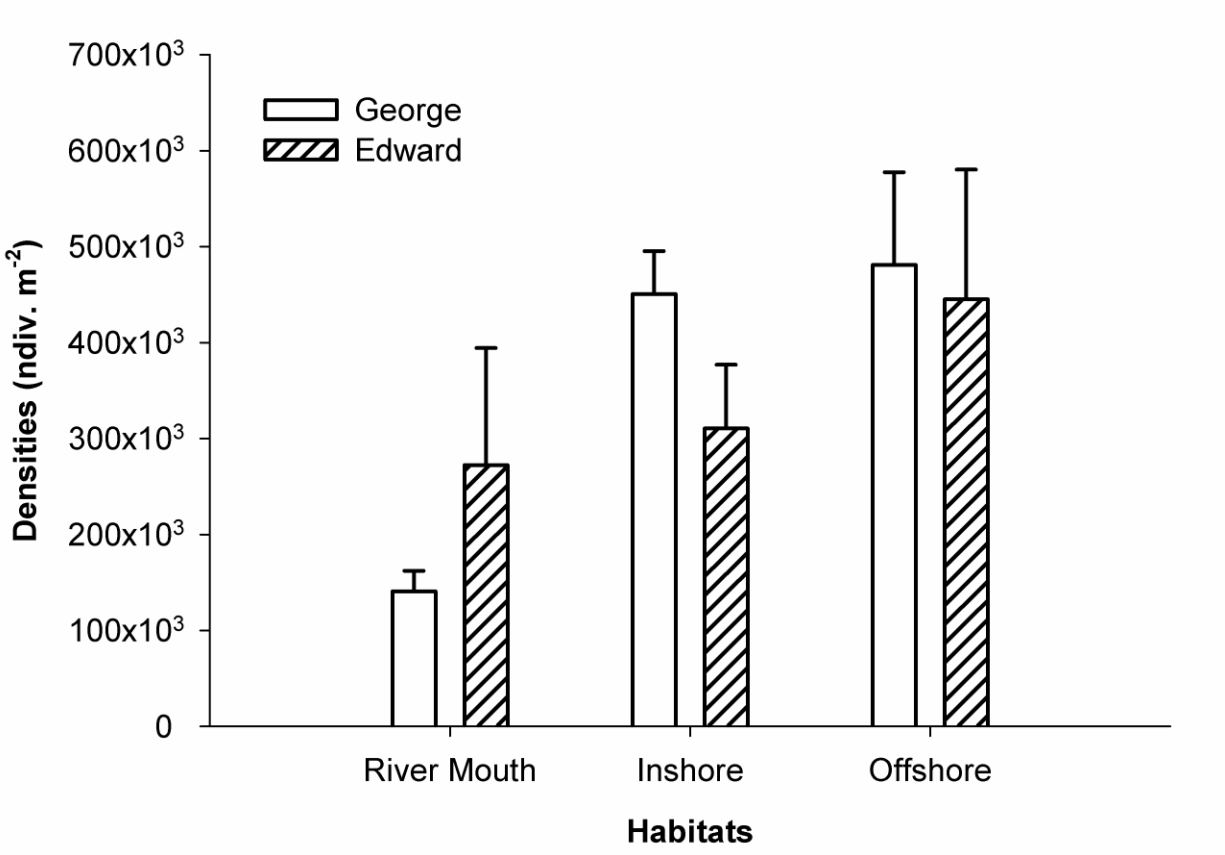


Figure 6. Zooplankton density estimates at field sites in lakes George and Edward.

4.5 Zooplankton in diets of commercial fishes

Parallel diet studies of commercial fish species, however indicated minimal use of the zooplankton community. The size ranges of both *C. gariepinus* and *B. docmac* obtained in this study (11- >50 cm TL) did not utilize the zooplankton food source in both lakes (Figs. 8 & 9). *O. niloticus* from Lake Edward was the only commercial fish species that incorporated zooplankton in its diet (Fig. 5), albeit in small proportions (10%). This observation is an indication of apparent preference for other/alternative food items for most fishes. It should however be noted that diets of the abundant but non-commercial haplochromines and other pelagic fishes, many of which are well known zooplanktivores, were not investigated in this study and this is considered to be a knowledge gap in the present data collection. Elsewhere, especially in Lake Victoria, pelagic fishes such as Mukene have been found to ingest large amounts (up to 70%) of zooplankton (Mwebaza-Ndawula (1998). In both lakes George and Edward, the fate of this rich food source (zooplankton) is not well understood at present.

4.6 Macro-benthos community in the environment

The macro-benthic communities of lakes George and Edward were in terms of numerical abundance dominated by midge fly larvae (*Chaoborus* sp, *Tanypus* sp, *Procladius* sp, *Clinotanypus* sp and *Chironomus* sp.) at inshore, offshore and river mouth habitats (Fig. 7). *Chaoborus* larvae were the most dominant item and were widely distributed especially in open water habitats, contributing 45-100% of total mean density of macro-benthos. Another notable group was the aquatic worms or oligochaetes, which exhibited widespread distribution patterns with peak abundance around the inshore areas in both lakes (Fig. 7). Mean total density of macro-benthos in the much shallower Lake George was low compared to Lake Edward and Kazinga channel; ranging from 98 ind.m^{-2} to 1863 ind.m^{-2}. Only few field sites had a mean total density greater than 1000 ind.m^{-2}. Mollusks were absent in Lake George collections but a community of mollusks, with *Melanoides tuberculata* as the main species occurred in Lake Edward, although in low densities.

The trend of molluscs scarcity in the present data represents a significant departure from the historical records by Mandahl-Barth, (1954) and Burgis et al. (1973). The current paucity is believed to be related low calcium content, as these organisms have a great need for divalent cations, especially calcium (Beadle 1981). In Lake Nabugabo, low molluscs' abundance was was attributed to low conductivity and low calcium concentration of 0.060 meq/l (Elftre et al., 2001). Conductivity of 200-800 µS/cm has been recorded in Lake Edward during this study (Table 1).

Earlier studies on Lake George (Burgis *et al*, 1973) established that the lake's biomass of 46. 8 g m^{-2} was dominated by phytoplankton by 95 % while open water standing crop biomass of benthos (0.305 g m^{-2}) contributed < 1% of total biomass. This benthos biomass comprised mainly oligochaetes, *Chironomus sp*, *Procladius* sp and Ostracoda. Most of these were encountered in the present study and indicate a general stability of the group overtime and therefore the potential to sustain fisheries production.

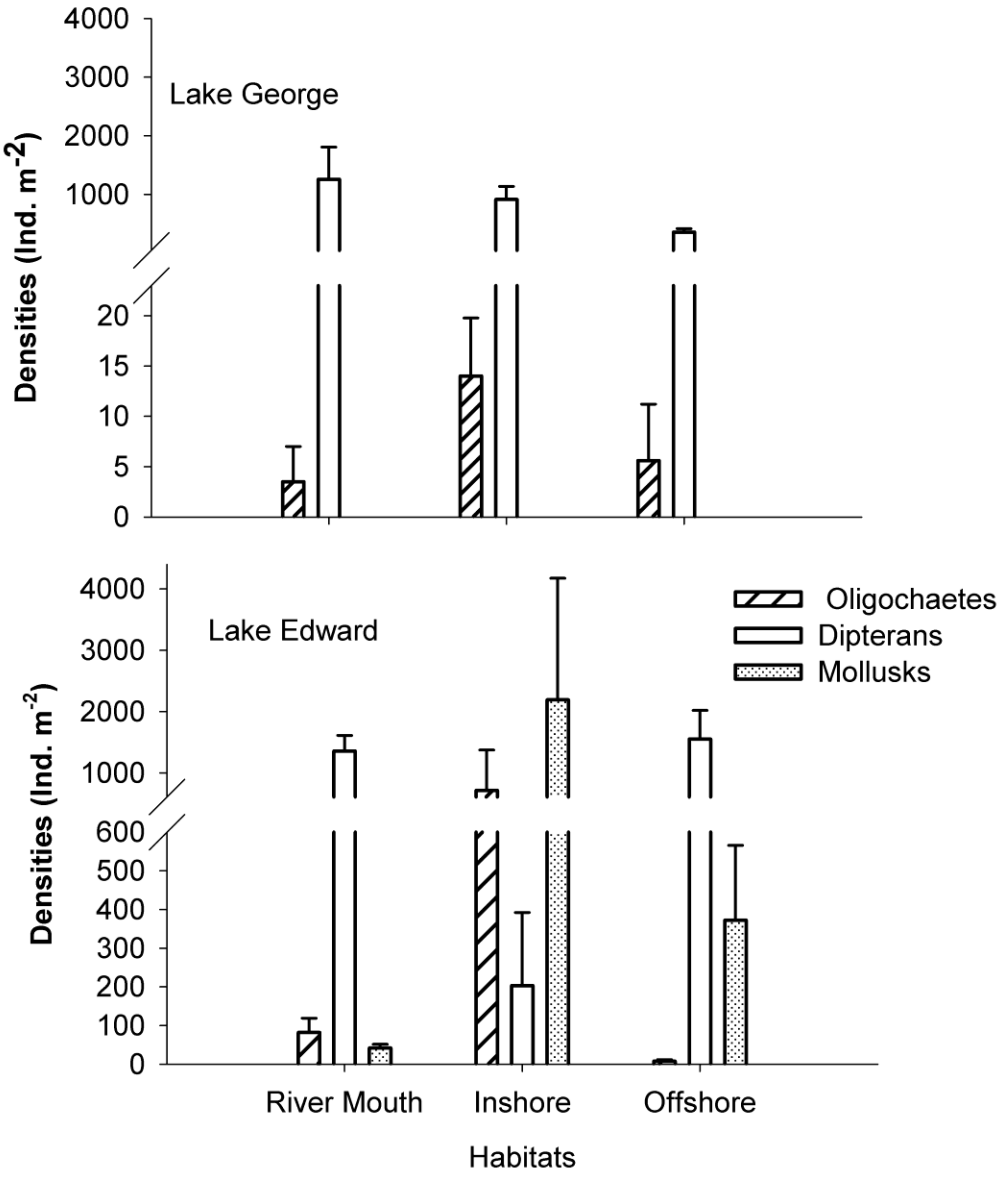


Figure 7. Density estimates of key macro-benthos fish food organisms from inshore, offshore and river mouth areas in lakes George and Edward

4.7 Macro-benthos in the diet of commercial fishes

Macro-invertebrate communities are known to serve two key ecological functions. They are a major source of food for demersal fishes and also serve as bio- indicators of environmental perturbations and ecosystem health.

Bagrus docmac from Lake Edward (Fig. 8) ingested two food categories: fish/fish remains (56%) and insects (44%). Key insect prey were midge fly larvae i.e. chaoborids & chironomids and dragon fly juveniles while haplochromines were the major fish prey. It is to be noted that even

though fish prey (haplochromines) were not assessed in this study as one of the key fish food organisms, their abundance in the lake was evident from their high contribution to the diet of *Bagrus docmac.*

Seventy percent (70%) of the diet of the African catfish, *Clarias gariepinus* in Lake Edward was sourced from the abundant insect commuity in the lake comprising *Chaoborus* larvae (59%), chironomids (8%), dragon fly (Odonata) juveniles (11%) and unidentified insect remains (IR). (Fig. 8). The remaining diet constituents were contributed largely by haplochromines and fish remains (22%), detritus and higher plant materials (HPM). Evidently, the diets of the two commercial fishes reflect a strong utilization of the more abundant fish food organisms in the lake i.e. the various insect groups and the haplochromine fish prey.

It is worthy to note that table fish species in the two lakes are subjected to very high fishing pressure (FAO, 2005), as such their populations are dominated by small-sized individuals that naturally feed on the abundant insects; hence the importance of insects in the diets of both *C. gariepinus* and *B. docmac*.

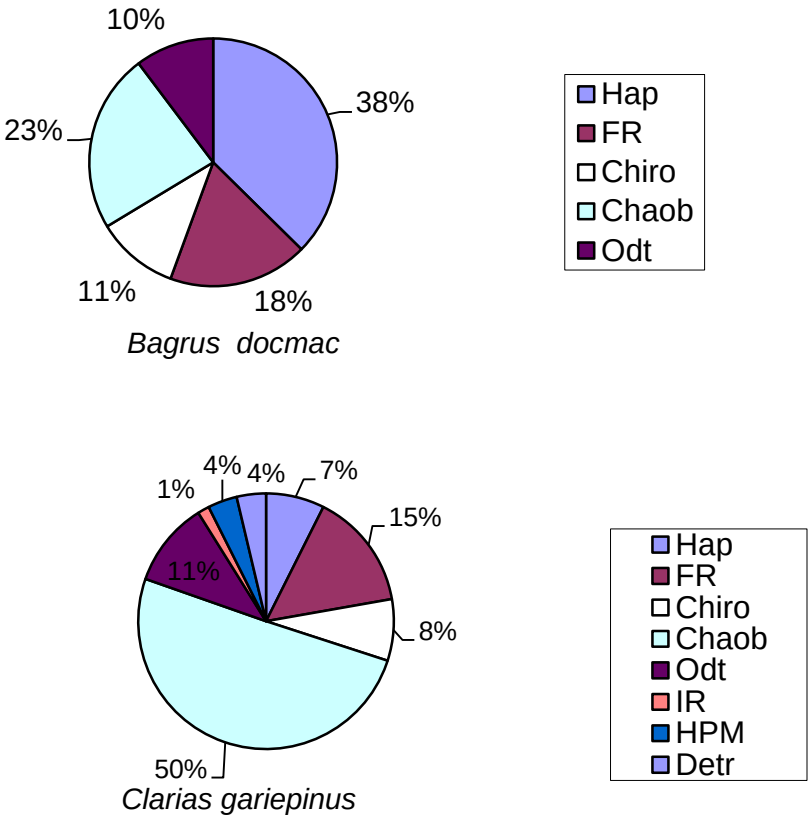


Figure 8. The diet components of *B. docmac,* and *C. gariepinus* Lake Edward (key to food items: IR= insect remains; Hap=haplochromines; FR=fish remains; Chiro=chironomids; Chaob=chaoborids; Odt= Odonata; HPM= higher plant materials Detr=detritus).

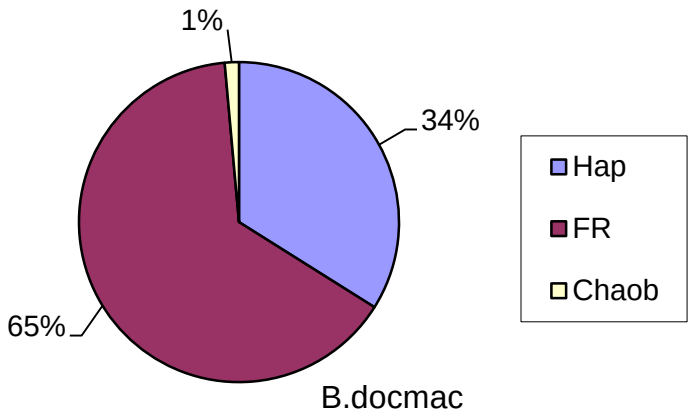


Figure 9. Diet of *B. docmac* in Lake George (key to diet items: Hap=haplochromines; FR=fish remains; Chaob=chaoborids.

In Lake George, the diet of *B. docmac* was much less diverse comprising largely prey fish items i.e. haplochromines and fish remains and with a negligible insect (chaoborids) component (Fig. 9).

4.8 Changes in diet of *B. docmac* with size of fish in Lake George

Fish prey (haplochromines and fish remains) was ingested by for all size classes of fish ranging from 11 to >50 cm TL) (Fig 10)**.**

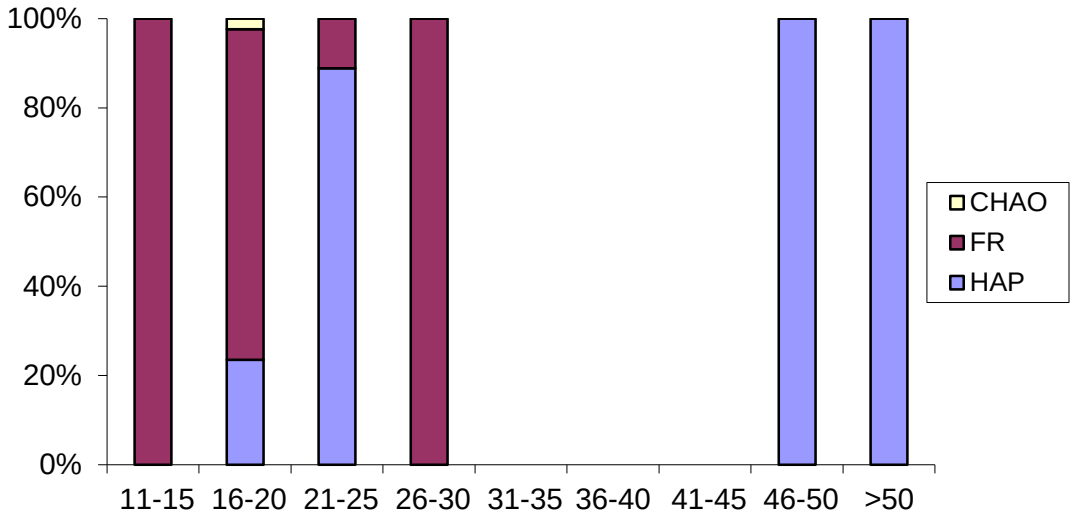


Figure 10. Diet variation with increasing fish size in *B. docmac* in Lake George (key to diet items: HAP=haplochromines; FR=fish remains; CHAOB=chaoborids.

4.9 Changes in diet of *B. docmac* with size of fish in Lake Edward

Small size classes of fish ingested a mixture of fish (haplochromines and fish remains) and insects (chaoborids, Odonata and chironomids) but fishes above 35 cm TL tended to specialize in fish prey only (Fig. 11).

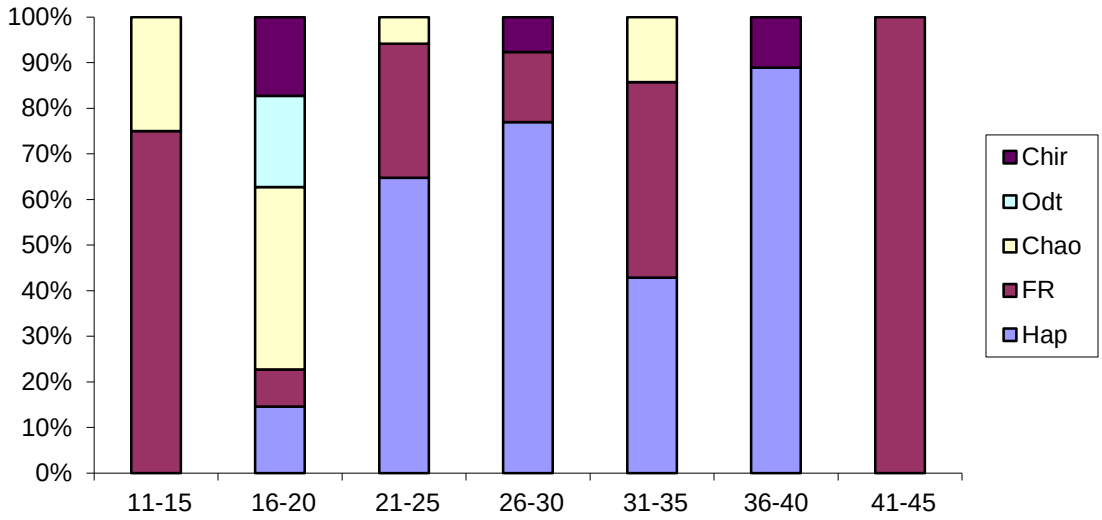


Figure 11. Diet variation with increasing fish size of *B. docmac* in Lake Edward (key to diet items: Hap=haplochromines; FR=fish remains; Chao=chaoborids; Chir=chironomids; Odt=Odonata).

4.10 Changes in diet of *C. gariepinus* with size of fish in Lake Edward

Small size classes of fish (16-35 cm TL) ingested largely insects (*Chaoborus*), but fish larger than 40 cm TL consumed a mixture of insects, fish prey, detritus and higher plant materials (HPM) (Fig. 12).

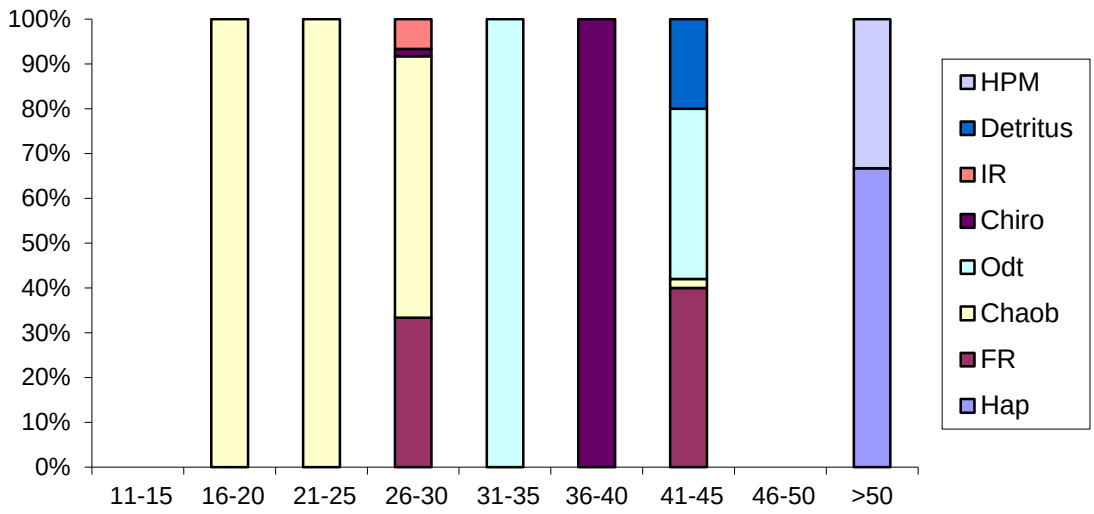


Figure 12. Diet variation with increasing fish size of *C. gariepinus* in Lake Edward (key to diet items: Hap=haplochromines; FR=fish remains; Chaob=chaoborids; Odt=Odonata; Chiro=chironomids; IR=insect remains; HPM=higher plant material).

4.11 Changes in diet of *O.niloticus* with size of fish in Lake George

No major changes in fish diet were observed within the two size classes (11-15 and 16-20 cm TL) of fish obtained but importance of the abundant blue green and green algae in this lake was reflected in diet proportions of these items (Fig. 13). Fish of small size classes below 10cm TL were not obtained in the samples (probably as a result sampling error) and ommision this is regarded as a gap in the collected data.

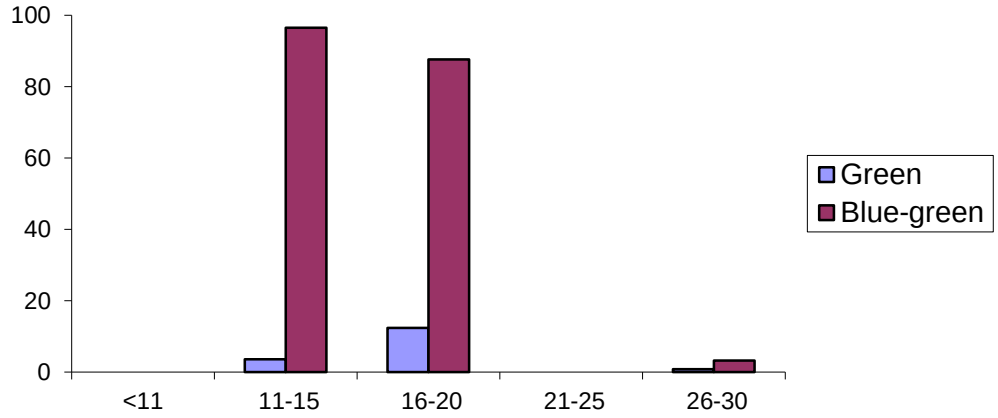


Figure 13. Diet variation with increasing fish size in *O.niloticus* in Lake George (key to diet items: Green= green algae; Blue-green=blue green algae.

4.12 Changes in diet of *O.niloticus* with size of fish in Lake Edward

Blue green algae and diatoms, were the most important diet items in the two size classes (16-20 and 21-25 cm TL) of fish obtained (Fig. 14). These key food items were supplemented by green algae, detritus, zooplankton and insect remains.

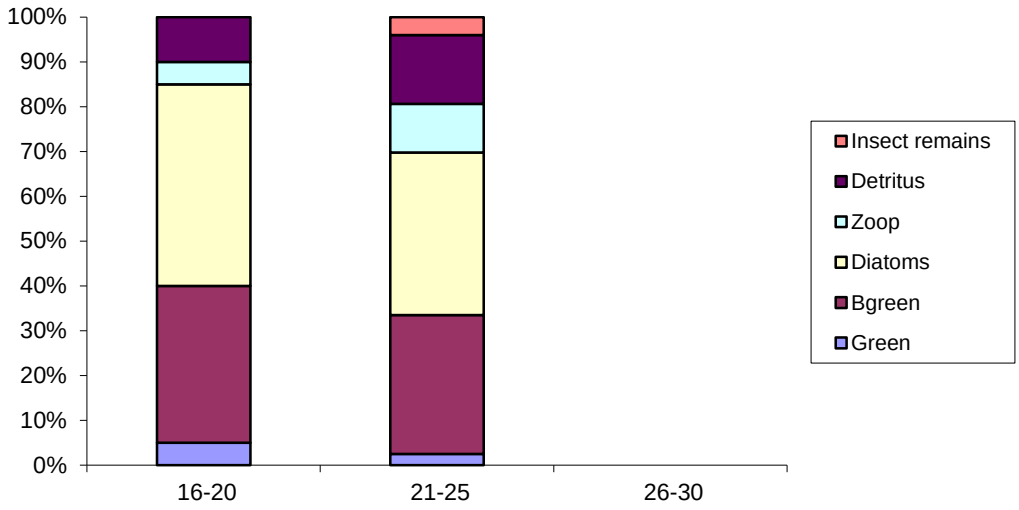


Figure 14. Diet variation with increasing fish size in *O.niloticus* in Lake Edward (key to diet items: Zoop=zooplankton; Bgreen=blue green algae; Green=green algae.

4.13 Energy densities in selected commercial fishes in lakes George and Edward

Energetic value in fish measured as caloric content is a function of fish bioenergetics. It provides information on how dietary energy ingested by fish is partitioned and used to meet its metabolic, physiological and nutritional needs under variable environmental conditions. Caloric density of fishes varies among individuals, seasons, age classes within populations, and geographically among populations. Variations in fish calorific content may to a big extent be explained by type and quantity of ingested materials and physiological changes during the life history of a given fish.

In Lake Edward, mean gross energy per unit gram of *C. gariepinus* was not significantly different from energy densities of *B. docmac* (P = 0.965) (Fig. 15). *O. niloticus* and Haplochromines had much lower energy densities than both *C. gariepinus* and *B. docmac*.

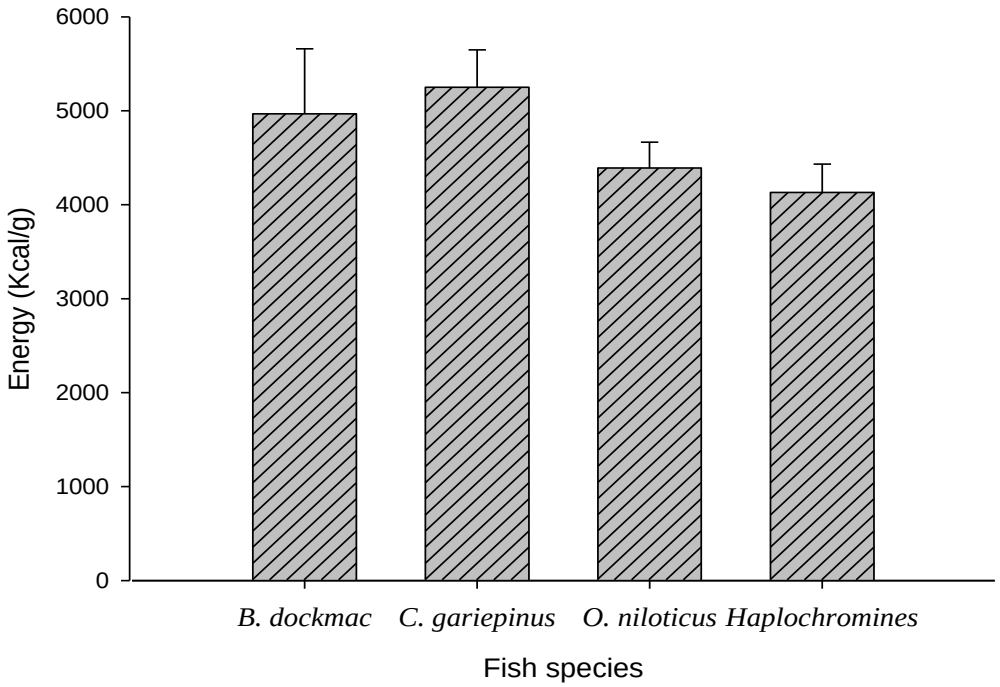


Figure 15. Energy densities of selected fish species of Lake Edward

Energy densities among fish species in Lake George followed a similar trend as in Lake Edward (Fig. 16).

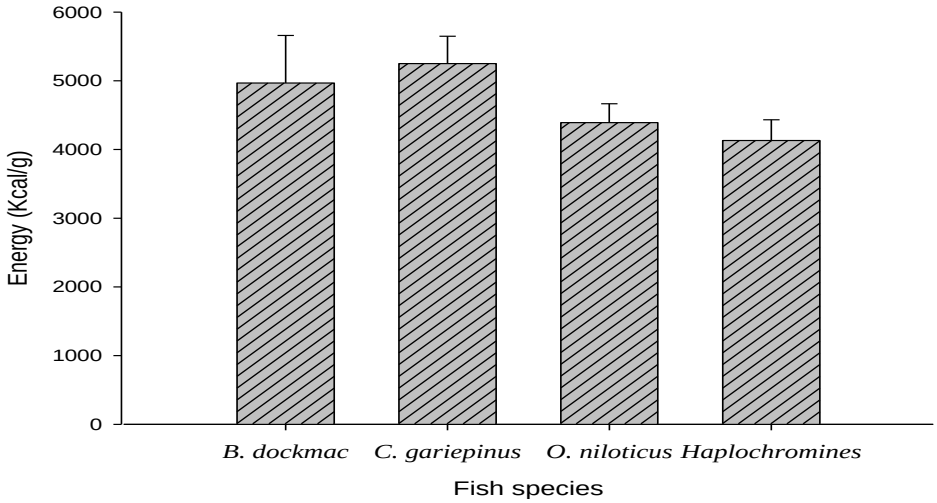


Figure 16. Energy densities of selected fish species of Lake George

A comparison of energy densities of fishes between the two lakes revealed significantly higher energy densities for all fish species in Lake Edward than in Lake George (Fig. 17). These preliminary findings indicated that *B. dockmac* and *C. gariepinus* confer the same energy per gram of fish tissue. The two species were also found to yield more energy per gram as when

compared to *O. niloticus* and haplochromines. It was noted that fishes from Lake Edward yield more energy than their counter parts from Lake George.

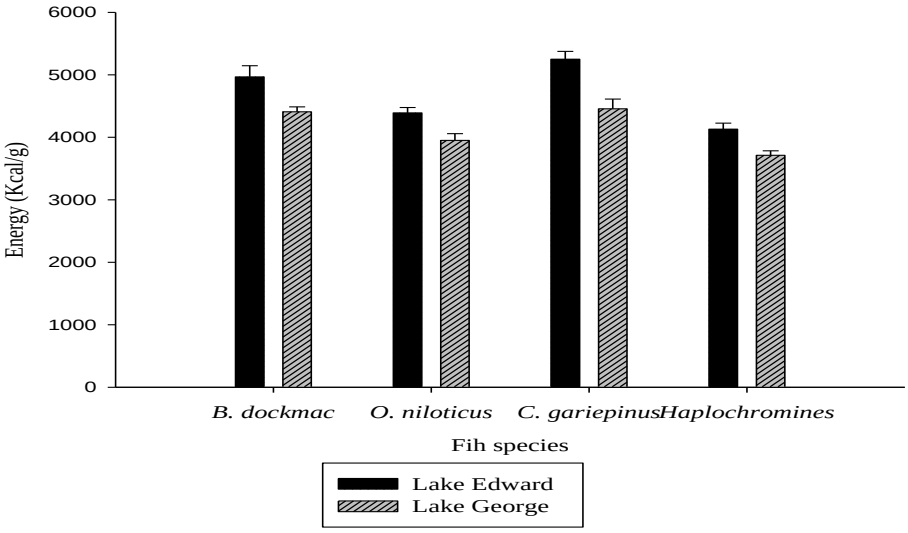


Figure 17. Comparison of mean energy (Kcal/g) of selected commercial fishes in lakes Edward and George

It is therefore probable that the dietary sources in Lake Edward (i.e. abundant insects and haplochromines) and prevailing conditions in general favour this better performance of the studied commercial fishes compared to the same fishes in Lake George with mostly algal food sources. It is also important to note that different fish species confer different energy returns to consumers i.e. there are differences in nutritional benefits.

5.0 CONCLUSIONS

1. The selected commercial fishes in lakes George and Edward (*Oreochromis niloticus, Bagrus docmac and Clarias gariepinus)* utilize a range of naturally available fish foods such as algae, zooplankton, macro-benthos and prey fishes (mainly haplochromines).
2. Algal communities are dominated by blue greens and diatoms and biomass levels are high (especially in Lake George) and indicate potential for nutritional support of fisheries
3. Zooplankton communities are dominated by cyclopoid copepods (*Thermocyclops hyalinus*) and with high abundance levels for nutrional support of fisheries
4. Macro-benthos communities are dominated by midge fly larvae and are in high abundances for nutritional support of fisheries
5. Although haplochromine fishes were not assessed in the environment as a source of fish food, its contribution to diets of two of the studied commercial fishes (*Bagrus docmac and Clarias gariepinus)* is tremendous
6. Lake Edward offered a wider food environment compared to Lake George that had a narrower food base dominated by high algal biomass.
7. The Nile tilapia, *Oreochromis niloticus* in Lake George was characterized by a two-item diet solely from algal sources i.e. the abundant blue-green and green algae while in Lake Edward the same species utilized a mixed diet comprising the abundant algae, zooplankton, detrital material and insects.
8. The African catfish, *Clarias gariepinus* and Semutundu, *B. docmac* shared a number of commom food items in their diets such as haplochromines/fish remains, insects but the diet spectrum of *C. gariepinus* was wider and included higher plant materials (HPM) and detritus.
9. Insects in Lake Edward appeared to be ingested in proportion to their prominent occurrence in the environment.
10. Small size classes of both *B. docmac* and *C. gariepinus* (< 15 cm TL) generally fed largely on insects while the diet of larger (mature) fishes was more diverse incorporating substantial proportions of fish prey (probably a reflection of the high abundance of this food item in the environment and higher energy demands expected in larger fishes).
11. A general shortcoming of the diet data was the absence of small or immature fish specimens (<10 cm TL) in the samples, which resulted in non-assessment of the diet of this category of young fishes.
12. Lake Edward evidently provided a richer food environment both for commercial fishes and the fishes in the lake conferred higher energy densities to the different fish species than was the case in Lake George.

6.0 RECOMMENDATIONS

1. The haplochromine community is believed to be abundant in both lakes and relatively unexploited at commercial level. The diet data generated in this study underscore the importance of this prey food item for both *C. gariepinus* and *B. docmac* even though its distribution and abundance patterns were not investigated. Subsequent studies should include this aspect as an integral part of the research agenda.
2. Small size classes (< 10 cm TL) of the investigated commercial fishes were not obtained in samples of the present investigation and this resulted in limited or no knowledge of the utilization of the available food environment by these small-sized (immature) fishes. This aspect should be given high priority in sampling designs of future research work.
3. Lake George's primary production is characterized by high algal biomass (95%), which provided the single most important food source for the Nile tilapia. With the knowledge that algal biomass is a reflection of the available nutrients, determination of nutrient budgets for the two lakes is necessary in order to reveal the main sources of nutrients that contribute to bulk algal production observed especially in Lake George. Knowledge of nutrient sources and quantities can guide management efforts towards regulation of nutrient influx into the lake.
4. At present it is not clear if the huge amounts of algae produced especially in Lake George is fed into the food chain or not. If not, then the residual algal biomass is likely to contribute to lower environmental quality in this lake which in turn may compromise its fish productivity potential. This might be a key explanation for the observed lower diversity of fish food organisms and energy equivalents in fish from Lake George when compared to those from Lake Edward. Existing laws and regulations on aquatic pollution need to be strengthened and rigorously enforced to avert potential impacts from excess nutrients and pollution and ensure appropriate management to sustain the key fish food sources and inherently the commercial fish species that derive nutrition from them.

7.0 REFERENCES

Beadle, L. C. (1966). Prolonged stratification and deoxygenation in tropical lakes. I. Crater lake Nkugute, Uganda, compared with Lakes Bunyoni and Edward. *Limnology and Oceanography* **11**: 152–163.

Boxshall, G. A. & Braide E. I. (1991) The freshwater cyclopoid copepods of Nigeria, with an illustrated key to all species. *Bull. Br. Mus. Nat. Hist. (Zool)* 57, 185–212.

Brown, M. R. Jeffrey, S. W. Volkman, J. K. and Dunstan, G. A. (1997). 'Nutritional properties of microalgae for mariculture'. *Aquaculture*, 151: 315-331.

Burgis, M.J., P.E.C. Darlington, I. G. Dunn, G.G. Ganf, F.J. Gwahaba and L.M. McGowan. 1973. The biomass and distribution of organisms in Lake George, Uganda. *Proc. R. Soc. Lond. B.* 184, 271-298.

Bwanika, G.N. Makanga, B. Kizito, Y. Chapman, L. J. and Balirwa, J. (2004). 'Observations on the biology of Nile tilapia, Oreochromis niloticus L., in two Ugandan crater lakes'. *African Journal of Ecology*, 42: 93-101.

Bwanika, G.N. Chapman, L.J. Kizito Y. and Balirwa, J. (2006). 'Cascading effects of introduced Nile perch (Lates niloticus) on the foraging ecology of Nile tilapia (*Oreochromi niloticus*)'. *Ecology of Fresh Water Fish*, 15: 470-481.

Efitre, J., Chapman, J. L. and Makanga, B. (2001). The inshore benthic macro-invertebrates of Lake Nabugabo, Uganda: seasonal and spatial patterns. *African Zoology* 36(2):205-216.

FAO, (2005). The first Lake Victoria Fisheries Organisation and FAO regional workshop on fishing effort and capacity on Lake Victoria, Dar es salaam, December 2005, Fisheries Report No. 796.

Fernando, C. H. (ed.), 2002. A guide to tropical freshwater zooplankton identification, ecology and impact on fisheries. Backhuys Publishers, Leiden. 291 pp.

Ganf, G.G, (1974). Phytoplankton Biomass and Distribution in a Shallow Eutrophic Lake (Lake George, Uganda). *Oecologia* (Berl.) 16:9-29.

Gophen, M., Drenner, R.W. and Vinyard, G.L. (1983). Fish introduction into Lake Kineret: Call for concern. *Fish. Mgmt*. 14: 43-45.

Greenwood, P.H. 1966. *The fishes of Uganda*. 2nd ed. The Uganda Society, Kampala.

John, D.M., B.A Whitton and A.J. Brook (eds.) 2002. The Freshwater Algal Flora of the British Isles. An identification Guide to Freshwater and Terrestrial Algae. The Natural History Museum and The British Phycological Society. University Press, Cambridge. United Kingdom. 702p

Korinek, V. (1999) A guide to limnetic species of Cladocera of African inland waters (Crustacea, Branchiopoda). *Int. Assoc. Theor. Appl. Limnol*. SIL. 1, 1–57.

Koste, W. (1978) Rotatoria. Die Radertiere Mitteleuropas.Ein Bestimmungwerk, begrundet vo Max Voig. Uberrordnung Monogononta. Gebruder Borntraeger, Berlin, Stuttgart.

Korovchinsky, N. M. (1992). Guides to the identification of the Micro-invertebrates of continental waters of the world. Dididae and Holopedidae (Crustacea, Daphniiformes). SPB Academic Publishing. The Hague. The Netherlands.

LVFO, (2007). Standard Operating Procedures (SOPs) for Collecting Biological Information from the Fishes of Lake Victoria. LVFO Standard Operating Procedures No. 1, LVFO, Jinja.

Mandahl-Barth, G. 1954. The freshwater mollusks of Uganda and adjacent territories. In Tervuren (1954). *Sciences Zoologiques* 32: 189-191 pp.

Meakins, R.H, (1976). Variations in the energy content of freshwater fish. *J.Fish. Biol*. 8: 8:221-224.

Merritt, R. W. and Cummins, K. W 1997. An introduction to the Aquatic Insects of North America, 3rd edition. Kendall/Hunt Publishing Co., Dubuque, Lowa.

Mosille, O. 1984. Phytoplankton species from Lake Victoria. In: Reports from The Haplochromis Ecology Survey Team (HEST) No. 30. Zoologisch Laboratorium, Morphology Department, Leiden University, the Netherlands.

Muli, R. J. (2005). Spatial variation of benthic macroinvertebrates, and the environmental factors influencing their distribution in Lake Victoria, Kenya. *Aquatic Ecosystem Health and Managemen* 8:147–157

Mwebaza-Ndawula, L. (1990). The role of invertebrate organisms in the fishery potential of Lake Victoria. In: Proceedings of workshop on the prevailing activities on Lake Victoria basin with particular reference to the fisheries of the Lake. pp56–60 (Bwathodi, J.O.P. ed.), Mwanza, Tanzania

Mwebaza-Ndawula, L. (1998) Distribution and abundance of zooplankton and *Rastrineobola argentea* (Pisces: Cyprinidae) and their trophic interactions in northern Lake Victoria. Ph.D. Thesis, University of Vienna, Austria. 162pp

Mwebaza-Ndawula, L. & Schiemer, F. (1997). Zooplankton consumption by *Rastrineobola argentea* (Cyprinidae) in Lake Victoria. *J. Fish. Biol. 51: 413.* (Supplement A, December 1997).

Mwebaza-Ndawula L, V. Kiggundu and W. Pabire Gandhi (2003). Diversity and abundance if invertebrates in the Victoria basin lakes and their role in fishery production. *Uganda Journal of Agricultural Sciences 8: 209-220.*

Mwebaza-Ndawula L, Kiggundu, V. and Ghandi, P.G. (2005). 'Aquatic invertebrates in Lake Victoria, Uganda portion'. Water Quality and Quantity Synthesis Final Report, Lake Victoria.

Nagayi-Yawe, K.J. Ogutu-Ohwayo, R. Kizito, Y.S. Balirwa, J.S. (2006). 'Population characteristics of Oreochromis esculentus in the Victoria and Kyoga lake basins. Implications for conservation and improvement of the stocks'. *African Journal of Ecology*, 44: 423-430.

Pennak, R.W. 1989. Freshwater invertebrates of the United States. John Wiley & Sons, New York.

Rich, F. (1933). Scientific results of the Cambridge Expedition to the East African Lakes, 1930–1931. 7. The algae. *J. Linn. Soc*. (Zool.) **38**, 249–275

Rutner-Kolisko A. (1974) Planktonic Rotifers: Biology and Taxonomy, Biological Station Lunz of the Austrian Academy of Science. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart

Semyalo, R.P. (2009). The effects of cyanobacteria on the growth, Survival, and behavior of a tropical fish (Nile tilapia) and zooplankton (Daphnia lumholtzi). PhD thesis. University of Bergen.

Semyalo, R. Rohrlack, T. Kayiira, D. Kizito, Y.S. Byarujali, S. Nyakairu, G. and Larsson, P. (2011). 'On the diet of Nile tilapia in two eutrophic tropical lakes containing toxin producing cyanobacteria'. *Limnologica*, 41: 30-36.

Talling, J.F., I.B. Talling (1965). The chemical composition of African lake waters. *Int. Rev. Hydrobiol.* **50**, 421–463

UNDF (Uganda Nile Discourse Forum), (2013). 'A baseline survey on Lakes Edward and Albert Integrated fisheries and Water Resources Management Project'. 3: 12.

Vollenwieder, R.A. (1968). Scientific fundamentals of the eutrophication of lakes and flowing streams, with particular reference to nitrogen and phosphorus as factors in eutrophication. O.E.C.D., Paris.

Worthington, E. B. (1931). Vertical movement of macroplankton. *Int. Rev. ges. Hydrobiol. Hydrogr.* 25: 394-436.