Bi-annual environment monitoring technical report for the SON cage fish culture site at Bugungu, Napoleon Gulf, northern Lake Victoria, December 2012

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EXECUTIVE SUMMARY

Source of the Nile Fish farm (SON) is located at Bugungu area in Napoleon Gulf, northern Lake Victoria. The proprietors of the farm requested NaFIRRI to provide technical assistance to undertake regular environment monitoring of the cage site as a mandatory requirement under the NEMA conditions. NAFIRRI agreed to undertake regular environment surveys in the cage area covering selected physical-chemical factors i.e. water column depth, water transparency, water column temperature, dissolved oxygen, pH, conductivity, nutrient status, algal and invertebrate communities (micro-invertebrates/zooplankton and macro-invertebrates/macro-benthos) as well as fish community. The first year-round quarterly surveys were completed for the year 2011. For the year 2012, SON management decided to change the frequency of the surveys from quarterly to biannual and the first such survey, was undertaken in June 2012. The second survey was undertaken in December 2012 and is the subject of this report. Results/observations made are presented in this technical report along with a scientific interpretation and discussion of the results with reference to possible impacts of the cage facilities to the water environment and aquatic biota.

SON cage study sites were coded as downstream of cages (DSC), within cages (WIC) and upstream of cages (USC). Physical-chemical parameters (water column temperature, dissolved oxygen, pH, conductivity, were measured in-situ with a pre-calibrated hydrolab at each site. A digital Echo Sounder was used to determine the total water column depth at each site. A black and white Secchi disc was used to determine water column transparency. Coordinate locations were determined with a GPS device.

Water samples for determination of nutrient levels and algal status were collected with a Van dorn sampler. Selected dissolved nutrients were analyzed by spectrophotometric methods. Zooplankton samples were sampled with a Nansen type plankton net of 0.25m mouth opening and 60µm Nitex mesh. Macro-benthic community was sampled with a Ponar grab of open jaw area, 238cm^2. All samples were taken in triplicate at each sampling point. Invertebrate samples were examined for species composition and abundance under binocular and inverted microscopes and with use of appropriate taxonomic manuals. Fish were sampled with fleets of gill-nets of varying mesh sizes, taxonomically identified and species numbers and weight recorded per site. Observations were also made on aspects of the biology and ecology of the fishes.

Measurements of total depth taken within and around the cage site showed that there was an insignificant variation in the depth profiles at all corresponding sites with USC still being the deepest site and WIC the shallowest.

Recorded Secchi depth (SD) values when compared with previous data showed that December 2011 and December 2012 had the lowest SD measurements compared to the other survey months (February, May and October 2011). It was noted that at the time of the present sampling the lake was generally calm and floating algae were visible and this appears to be the

reason for the low Secchi depth values. This observation was comparable with the trend in chlorophyll-a and total suspended solids.

Dissolved oxygen concentrations in the water column were compared according to water depths (surface, mid water and near bottom water). Concentrations at different depth levels (range: 6.72 ± 0.09 to 7.97 ± 0.87mg/L) indicated that it is in sufficient amounts and well above the recommended level (5.0mg/L) for warm and cold water fisheries as well as fish grown under cage conditions.

Temperatures were measured along the water column ranged between 25.93 ± 0.00 and 26.48 ± 0.07 °C and fell within levels recommended for aquaculture operations. The observed slight variation in water temperature is not likely to significantly impact on the performance of the fish within and around the fish cages.
An upward trend in pH was observed from USC towards DSC with the highest being at WIC. The pH range recorded (7.8 and 8.1) indicated that water conditions, in this aspect, were still good for fish survival in the area.
Electrical conductivity was between 99.4 ± 0.08 to 102.23 ± 1.4µScm^{-1} and this is considered to be typical of Lake Victoria waters. There seemed to be sufficient flushing of wastes around the cage area by the river current and that probably explains the observed low conductivity values recorded.

Total Nitrogen (TN) was highest at WIC and was also higher than Total Phosphorus (TP) and Soluble Reactive Silica (SRSi). TP and SRSi concentrations did not vary much between sites. TN was high and above 20µg/L (0.02ppm) threshold. Ask Henry what the threshold means
Ammonia concentration was lowest at WIC (ca. 3ug/l) while the highest concentration was below 4µg/L. Ask Henry SRP followed a comparable trend. The acceptable range for NO_2-N is between 1000 and 100µg/L compared to the low concentration level recorded around and within the cages (4 µg/L).
Nitrate was generally high (up to about 30µg/L) compared to NO_2-N, NH3 and SRP. It exhibited an increasing trend from USC through WIC to DSC.
Chlorophyll-a was highest at WIC (ca 15ug/l) and thereafter registering much lower concentrations at both USC and DSC. On the other hand, TSS was lowest at WIC and considerably higher at USC and DSC.

Blue-green algae (BG) had the highest biomass at DSC (ca.5000ug/l) which decreased progressively through WIC (ca. 2300 ug/l) to USC (ca. 1800ug/l). Diatom biomass varied within small limits across sites and was generally below 1000ug/l. Green algal biomass was very low at all three sites as was that of 'other' algae group.

Zooplankton species varied from 10 to 17 between the three sites with a narrow difference in total species number between sites. Copepod species numbers were nearly evenly spread across the three sampling sites (5-6 species) and rotifer species followed a comparable trend but with a minor depression at WIC. Cladocerans had a uniform spread (2 species) across the three sites. Least number of total zooplankton species was found at WIC. Common and more

dominant copepods species were: *Tropocyclops tenellus, Thermocyclops neglectus, Thermocyclops emini, Thermodiaptomus galeboides,* cyclopoid copepodites and nauplius larvae Rare copepods included *Mesocyclops* sp. and *Thermocyclops incisus*. Cladoceran species were generally rare. *Synchaeta* sp. was the more abundant rotiferan species. Copepoda were the most numerically abundant taxon in all sites, ranging between 112,100 at DSC and 126,700 ind. m^{-2} at WIC while Cladocera ranged between 550 at USC and 1000 ind.m^{-2} at DSC. Rotiferan densities were lowest at WIC 2000 ind. m^{-2} and higher at DSC 2200 ind. m^{-2} and 2300 ind. m^{-2} at USC. The 'within cages' transect registered the highest total numerical abundance (129,700 ind. m^{-2}).

Four broad groups of macro-benthos constituted the community: Mollusks (Bivalvia and Gastropoda); Ephemeroptera; Diptera, and Annelida (Hirudinea and Oligochaeta) with a total of 19 taxa collected. There was a general decrease in the numerical abundance of mollusks in the December samples compared to the June 2012 survey. On the other hand, there was a decrease the number of mollusk taxa/species registered in December compared to the June 2012 survey. The highest concentration of mollusks was in the WIC site with gastropods *B. unicolor* and bivalve *C. africana* leading with 364 and 336 ind. m^{-2} respectively. The contribution of dipterans (chironomids and chaoborids) was also unusually high particularly at the WIC area.

Twelve (12) fish species: 7 haplochromines (Nkejje) and 5 non-haplochromines), belonging to 5 families were recorded. *Synodontis afrofischeri* dominated the catch by numbers with 34.9% while by weight the *Synodontis victoriae* dominated with 37.2% followed by Nile perch (*Lates niloticus*) at 32.8%. Lowest fish diversity (4 species) occurred at USC while the highest diversity (9 species) was recorded at DSC) while 7 species were obtained at WIC. Fish abundance (weight) was highest at WIC (54.3%) and lowest at USC (7.6%). The 7 species of haplochromines obtained belonged to 7 genera. Highest haplochromine diversity (5 species) was recorded at DSC while 3 species were recovered at WIC while no fish was recovered from USC. The most abundant haplochromines belonged to the genus *Astatotilapia* (80.6%) followed by *Psammochromis* sp (13.6%), *Paralabidochromis*, *Ptyochromis* and *Xysitchromis* contributing 0.97% each.
Fish catch rates in terms of numbers and weight, were highest at WIC with 19.8 fish per net 1161.1g per net respectively. Overall mean rates for December, 2012 were 12.13 by numbers 842.4g by weight.

In conclusion, water quality conditions at SON cage farm has not indicated much change from that reported in the June 2012 survey, which indicated good water environment for aquatic biota in general. Current levels of nutrient parameters are well below those considered toxic to fish and other organisms. The high chlorophyll-a concentration at WC is likely due to be available nutrients in the water column part of which may be from remnants of un-eaten fish feeds and metabolic products of the caged fish. Zooplankton species richness appeared depressed at the within cages/WIC site while numerical abundance was highest at this same site (WIC), probably suggesting minimal impact of cage operations on the community at this time of the year.

The apparent high profile of Diptera, Gastropoda and Annelida in terms of numerical abundance particularly at WIC and USC may be considered to be a positive development as these all constitute important food sources for wild fishes in the area although it was not clear what influence the fish cage may have had. Current field observations on the fish community also indicated little or no effect of the fish cage culture on the wild population of fishes in the area, but high fish abundance and catch rates at WIC were noteworthy.
Observed high TN, NO3-N and chlorophyll-a values, high zooplankton, macro-benthos, fish abundance and catch rates at WIC site during this survey provides a strong indication so far of possible impacts (positive!) from cage operations to the water natural environment and biota.

Based on the present field observation and results which show both similarities and variations of data collected during the 2011 and June 2012 surveys, it is recommended to return to the quarterly routine of environment monitoring. This suggestion is particularly important given the increased number of cage units (up to 300 and over) which may cause development of deleterious effects to the water quality and biota from cage operations and products. The quarterly routine would enable timely detection of any such effects in order to institute appropriate remedial measures as well as follow possible seasonal changes in the water quality that may occur in the cage area. In the next round of environmental monitoring, there will also be need to relocate at least the USC sample transect as it currently lies in an areas covered by cages due to expansion of the cage area from the time the first surveys were undertaken in February 2011.
It is further recommended that the issue cage concentration in any one area should be carefully controlled in order to avert development of possible deleterious environmental impacts from cage operations that may drastically alter key aspects of the ecology in the areas under fish cage culture.

1.0 Background

It is an obligatory requirement of the National Environment Management Authority (NEMA) of Uganda to undertake regular environment monitoring at all sites conceived to be sensitive to the natural environment. Fish cage culture in natural water bodies, which is currently being promoted in Uganda, is one such area that requires regular environment monitoring by a competent environment agency. The National Fisheries Resources Research Institute, NaFIRRI undertook and completed quarterly environment monitoring surveys at Bugungu cage site for the year 2011. While for the year 2011 quarterly monitoring surveys were carried out at Source of the Nile (SON) fish farm, the client decided that NaFIRRI undertakes half-yearly surveys in 2012 . The first such survey was undertaken in June 2012 and the second one was undertaken in December 2012. The monitoring reports for the 2011 surveys and the most recent one in June 2012 indicated no serious environmental perturbations at the site save for some evidence of incipient pollution effects especially at the lower production levels (algae, zooplankton and macro-benthos (see 2011 and June 2012 SON survey reports). These included periodic algal blooms, reduced species diversity and numerical abundance of zooplankton, increase in abundance of pollution-tolerant macro-benthic forms (mollusks and dipteran larvae) and non-occurrence of the most pollution-sensitive macro-invertebrates (EPTs) at the transect with cages, WIC. These observations appear to suggest that as the number of cage units increase in any one culture site, there is a likelihood of development of impacts to both the natural water environment as well as sections of the aquatic biota. Environmental impacts may arise from bio-deposits of fish excretion, residual fish feeds, accumulation of faecal materials, pollutants etc which may cause diurnal spells of low dissolved oxygen, algal blooms and many others (Nash (2001). Such local stress factors, if persistent can lead to negative changes in the in diversity, distribution and abundance patterns of some aquatic communities which may affect fish production and productivity patterns in areas of fish cage operations.

NaFIRRI undertook the second half-yearly environmental monitoring during December 2012. As in the previous surveys, the parameters investigated included water column depth profiles, Secchi depth transparency, selected physical chemical parameters (water temperature, dissolved oxygen, pH, electrical conductivity), nutrients (Soluble Reactive Phosphorus – SRP; Nitrite nitrogen- NO_2-N; Ammonium-nitrogen- NH_3-N; and Total suspended solids- TSS) algae, zooplankton, macro-benthos and fish communities at three sites within the fish farm. The first site is located upstream of the cages (USC), the second site was within the cage rows (WIC) and the third was downstream of the cages (DSC).

The present report is the second half- yearly survey report and presents field observations made for the survey undertaken in December 2012. The report provides a scientific interpretation and discussion of the results with reference to possible impacts of the cage facilities to the water environment and the selected aquatic biota in and around the cage site. Survey conclusions are derived from the data generated and recommendations for cage operations in the lake are provided.

2.0 Materials and Methods

Field measurements and sample collections were taken at three points along transects representing USC, WIC and DSC with respect to the location and areal spread of the fish cages. At each sampling point, replicate samples were taken for each parameter under investigation for the purpose of assessing variation in each parameter at each field site. Coordinate locations for each site were determined with a GPS device, recorded and used to prepare a site locations map (Figure 1).

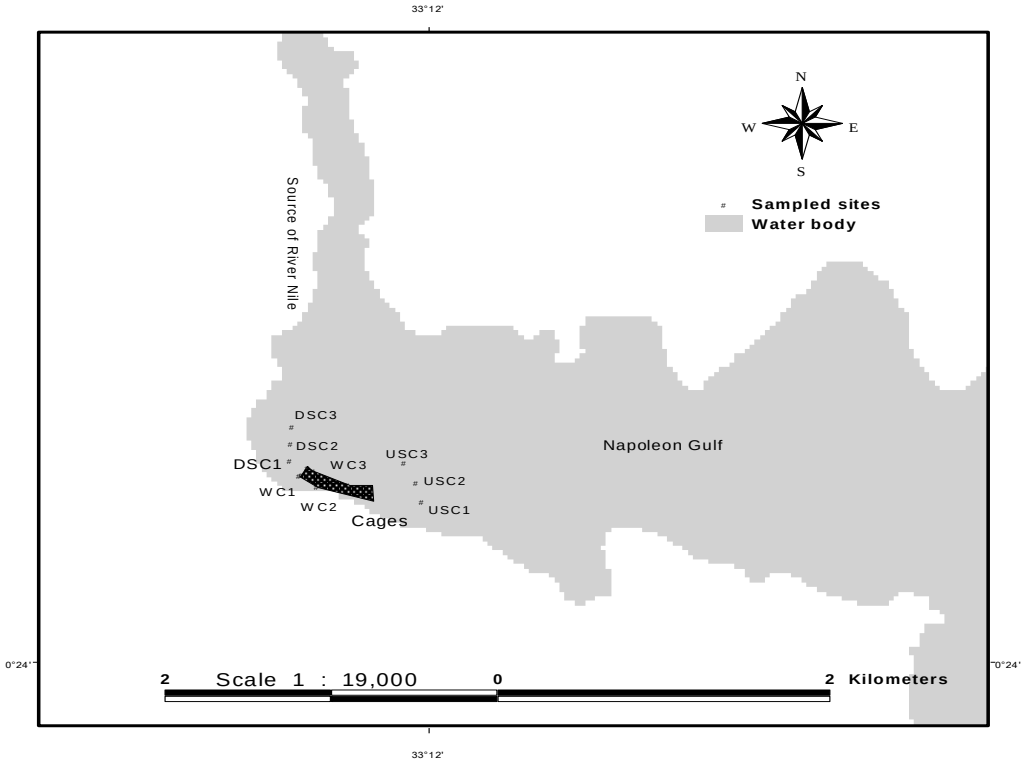


Figure 1. Map of the study area showing location of SON Fish Farm and study areas: USC- upstream of cages; WIC- within cages and DSC- downstream of cages, in Napoleon Gulf, northern Lake Victoria.

2.1 Depth profiles and water transparency

A digital Echo Sounder was used to determine the total water column depth at each sampling point. A black and white Secchi disc harnessed with a 1-metre marked rope was used to measure water column transparency.

2.2 Physical-chemical environment

Physical-chemical parameters (water column temperature, dissolved oxygen, pH and conductivity, were measured in-situ with a pre-calibrated hydrolab containing a data logger at each site and the data was down-loaded on to a computer for subsequent analysis.

2.3 Nutrient status

Water samples for the determination of nutrients and algae status were collected with a Van Dorn sampler, stored in clean, labeled plastic bottles. Water samples for determination of dissolved nutrients i.e. Soluble Reactive Phosphorus (SRP), Ammonium-nitrogen (NH_3-N) and Nitrite-nitrogen (NO_2-N) were filtered and analyzed by spectrophotometric methods following procedures by Stantoin et al. (1977). Water samples were also analyzed for total suspended solids (TSS).

2.4 Micro-invertebrates (zooplankton) and Macro-invertebrates (macro-benthos)

The zooplankton community was sampled in triplicates at each field point using a conical plankton net of 0.25 metre mouth diameter and 60 µm mesh. Filtered samples were placed in clean plastic bottles and fixed wit h 4% sugar formalin. In the laboratory, samples were rinsed in tap water over a 50 µm nitex mesh and diluted to a suitable volume depending on the concentration of each sample. Series of 2, 2, and 5 sub-samples were taken from a well agitated sample using a calibrated automatic bulb pipette, each introduced on to a plankton counting chamber and examined under an inverted microscope at x100 magnification. Individual organisms were taxonomically identified using zooplankton taxonomic manuals by Boxshall & Braide 1991; Korinek 1999; Korovchinsky 1992; Koste 1978. Members of each species were enumerated and recorded.

Macro-benthos community was sampled by taking sediment samples with a Ponar grab (open jaw area, 238cm^2) harnessed with a nylon rope marked at 1- metre intervals. Three grab hauls were taken from each sampling point and each kept separately for subsequent laboratory analysis. The bottom type and sediment texture was determined and described from visual observations and feel between two fingers. Each grab sample was concentrated, placed in clean, labeled sample bottle, and preserved with 5% formalin. In the laboratory, each sample was rinsed with tap water and spread on to a clean white plastic tray. Benthic organisms were sorted from the sediment using forceps and the sorted sample was examined under a dissecting binocular microscope at x 400 magnification. Taxonomically identifification was done using manuals by Pennak (1953), Mandhal-barth, (1954) and Epler (1995). All taxa were recorded and individuals of each taxon enumerated.

2.5 Fish community

Three fleets of gill-nets comprising panels of mesh sizes 1” to 5.5” in 0.5” increments, and 6 to 8 in 1” increments were set overnight at USC, WIC and DSC. The nets were set between 1800hr and 1900hr on the field day and removed between 0600hr and 0700hr the following day.

Fish species caught by different nets in each fleet were sorted and identified as in Greenwood (1966). Specimens of fishes not easily identifiable in the field especially the haplochromines were given field names, and preserved for more detailed laboratory taxonomic procedures as in Greenwood (1981). For each species, the number, total weight (g) and individual lengths (cm) of the fish were recorded. Fork length (FL) was measured for all fish species with forked caudal fins.

Biometric data (Total and Standard length, body weight, sex and gonad maturity state, stomach fullness and fat content) were determined and recorded for individual fishes. Fish stomachs were carefully removed placed in clean, labeled plastic sample bottles and preserved in 5% formalin for laboratory analysis of the contents as in Bagenal & Braun (1978). Fish specimens were also examined for any infection (parasitic or bacterial) both on the surface and within the gut cavity.

3.0 Results, inferences and discussion of data

3.1 Physical-chemical environment

3.1.1 Total depth profile

Total depth has been monitored for likely changes that could arise due to sedimentation. Measurements for total depth were taken within and around the cage site. Total depths at similar points were compared with corresponding depth measurements taken in previous surveys (2011 & June 2012). The results indicated that there is an insignificant variation in the depth profiles at all similar sites. Sites at the USC transect remain deepest area while those at WIC are the shallowest. However, in June 2012 survey, the sudden increase in total depth observed at WIC was most likely due to possible missing of the exact spot of sampling. In December 2012 the total depth was slightly deeper probably due to sedimentation (Fig. 2).

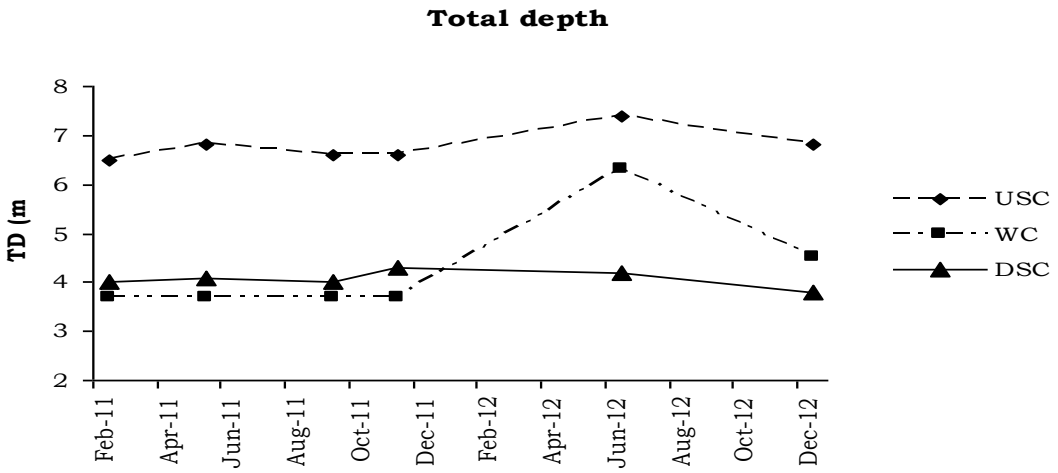


Figure 2. Depth profiles at SON cage fish farm, February 2011-December 2012.

3.1.2 Secchi depth profile

Secchi depth (SD) measurements were determined to provide information about water clarity with respect to light penetration through the water column. The presence of suspended particles that comprises floating algae, re-suspended sediment particles from the lake bottom all bear influence on the Secchi depth reading. Comparison of the Secchi depth values, it was noted that December 2011 and 2012 values were the lowest SD measurements; a likely

indication of seasonality of suspended matter in the water column in this area. Field observations at the time of sampling indicated that the lake was generally calm and floating algae was visible. The presence of the floating algae therefore is a likely reason for the low secchi depth (Fig. 3). This observation corroborates other data on chlorophyll- a and suspended solids/TSS (Fig. 8).

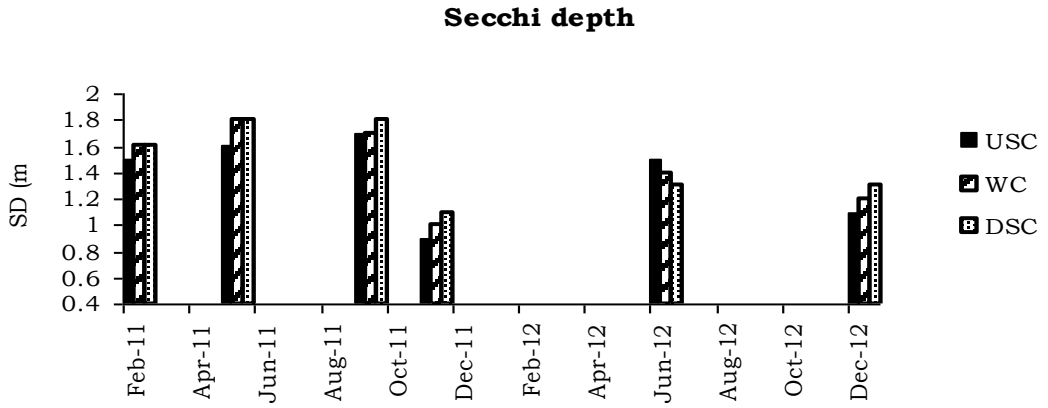


Figure 3. Secchi depth profiles, at SON cage fish farm, February 2011-December 2012.

3.1.3 Oxygen concentrations

Dissolved oxygen (DO) concentrations in the water column based on specific depths (surface, mid water and near bottom water) with respect to USC, WIC and DSC field sites, ranged from 6.72 ± 0.09 to 7.97 ± 0.87mg/L and indicated that there are sufficient amounts of DO to support aquatic biota (Table 1). The range was notably above the recommended level (5.0mg/L) for warm and cold water fisheries as well as those grown under cage conditions (Joseph *et al*, 1993). The observed levels of dissolved oxygen are likely to be associated with continued photosynthetic process by the abundant algae within and around the cages as well and in addition to dissolution of the gas from the atmosphere. The availability of sufficient dissolved oxygen implies that the fishes in the cages and wild stocks in the area have enough oxygen supply for their growth and maintenance and there are probably no negative impacts from the cage activities on this parameter.

Table 1. Concentrations (mg/l: mean ± stdev) of dissolved oxygen at various water column positions at SON cage fish farm, December 2012

Depth	USC	WIC	DSC
Surface	7.97 ± 0.87	7.26 ± 0.43	6.72 ± 0.09
Mid water	7.01 ± 0.38	7.17 ± 0.37	6.86 ± 1.58
Near bottom	7.30 ± 0.01	6.75 ± 0.30	6.87 ± 0.00

3.1.4 Temperature (°C)

Temperatures measured along the water column had a range of between 25.93 ± 0.00 and 26.48 ± 0.07 °C (Table 2). The lowest temperature (25.93 ± 0.16) recorded at WIC near the lake bottom indicates a slightly cooler condition at this particular site compared to the other sites. The observed slight variation in temperature may not significantly impact on the fish within and around the fish cages to the extent of impairing their normal growth. High temperature variation is known to impact on the chemical and biological processes suitable for cage aquaculture production. The recorded temperatures were found to fall within the range for fish under aquaculture and natural conditions. It is to be noted that fish are capable of adjusting to suitable body temperatures and metabolic rate. In the event of any changes in temperature conditions they adjust by moving between cooler or warmer waters (Joseph *et al*, 1993) during conditions of thermal stratification. Warmer waters, due to high temperatures, may cause less oxygen to diffuse into the water and also provide suitable conditions for disease-causing agents, which in some cases, may have negative impacts on cage fish (Heather, 2012).

Table 2. Temperature variations (mean ± stdev) at different water column positions at SON cage fish farm, December 2012

Depth	USC	WIC	DSC
Surface	26.48 ± 0.07	26.32 ± 0.04	26.36 ± 0.21
Mid water	26.30 ± 0.03	26.21 ± 0.10	26.61 ± 6.15
Near bottom	26.25 ± 0.00	25.93 ± 0.16	26.67 ± 0.00

3.1.5 pH profiles

An upward but non-significant trend in pH was observed from USC towards DSC with the highest being at WIC and DSC (ca. 8.1) (Fig. 4). High pH values above 7 indicate of alkaline conditions. At higher pH, more ammonia may form and this is problematic to fish health and survival (Heather, 2012). Fish normally require water with a pH range of between pH 6 – 9 (Joseph, 1993). The observed pH range between 7.8 and 8.1 indicates that the prevailing conditions at the cage site are good for fish survival. These alkaline conditions may be attributed to the presence of algae and other green plants that photosynthesize during day by consuming the available carbon dioxide that would otherwise dissolve in the water to form weak carbonic acid that is responsible for lowering of the pH.

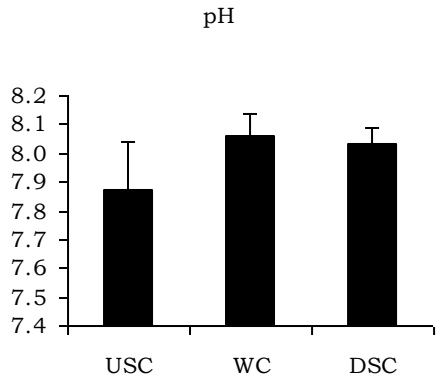


Figure 4. pH profiles across study sites at SON cage fish farm, December 2012.

3.1.6 Conductivity, µScm^{-1}

Measure of electrical conductivity relates to how much dissolved inorganic ions including those ions are in the water (Heather, 2012). Conductivity also provides a picture of whether the water is soft or hard. High conductivity values (> 110 µScm^{-1}) mean that the water is tending towards salinity and hence becoming hard. This may impact negatively on the osmoregulatory capacity of the freshwater fish to balance between ion intake and discharge from their blood system, resulting into physiological stress (Heather, 2012). Electrical conductivity was between 99.4 ± 0.08 to 102.23 ± 1.4µScm^{-1} (Table 3) compared to typical Lake Victoria range between 90 and 110µSCm^{-1} except where concentrated industrial and urban sewage waters enter the lake. Urban sewage, industrial effluents, and to some extent excreta from the fish cages introduces solid materials that could dissolve and hence alter the conductivity of the water. It is apparent that continuous flushing of the wastes deposited around the cage (WIC) by the water currents probably lowers conductivity values to make them comparable to those at the control site (USC) and downstream (DSC).

Table 3. Conductivity values across study sites at various water column positions at SON cage fish farm, December 2012.

Depth	USC	WIC	DSC
Surface	102.23 ± 1.40	100.86 ± 1.40	101.1 ± 0.52
Mid water	100.95 ± 0.54	100.45 ± 0.42	99.9 ± 23.48
Near bottom	100.55 ± 0.14	100.55 ± 0.14	99.4 ± 0.08

3.2 Nutrient status around the fish cages

Besides chemical materials that naturally occur in the water, fish and other aquatic organisms excrete nitrogenous compounds into the water and this makes it vital to monitor the various nutrient levels in areas of cage fish culture. Total nitrogen, ammonia, nitrates and nitrites constitute the nitrogenous compounds whereas other nutrients such as soluble reactive

phosphorus (SRP) and soluble reactive silica (SRSi), chlorophyll-a are equally important elements associated with cage culture and natural fish production. These elements were compared amongst themselves in the order of TN, TP and SRSi, NO_2, NH_3 and SRP, and lastly Chll-a and Total suspended solids (TSS).

3.2.1 TN, TP and SRSi

TN concentration was high at WIC (ca. 260 ug/l) and generally had higher concentrations than TP and SRSi across the three study sites (Figure 5). TP and SRSi concentrations did not vary much between the three sites. TN was notably high above 20µg/L (0.02ppm) threshold.

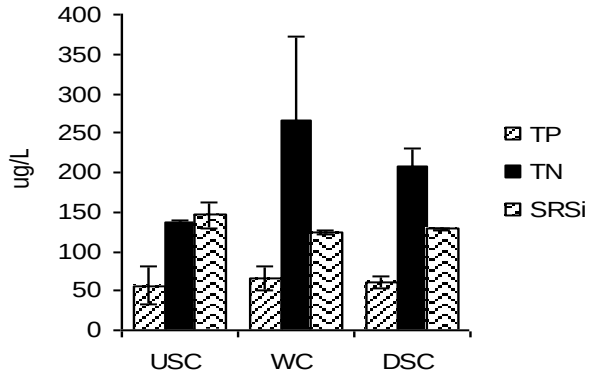


Figure 5. Variation of TP, TN and SRSi across study sites at SON cage fish farm, December 2012

3.2.2 NO_2-N, SRP and NH_3

Ammonium-N concentration decreased from USC towards WIC but increased at DSC although the highest concentration was below 4µg/L. SRP was also high at USC and DSC and lowest at WIC. It was also higher than NH_4-N and NO_2-N at the three sites. The low ammonia concentration could be attributed to the continued natural process of its removal from water (Joseph, *et al*. 1993). It is reported that when continuously exposed to un-ionized total ammonium nitrogen at a level beyond 20 µg/L (0.02ppm) fish could experience reduced growth and become susceptible to disease infections thereby impairing fish survival (Joseph, *et al*, 1993).

Nitrite is toxic to fish at a concentration above 500µg/L and at high levels it causes 'brown blood disease' that is responsible for reduced fish growth (Joseph, *et al*, 1993). The acceptable range for NO_2-N is between 1000 and 100µg/L. The concentration levels around and within the cages were notably low (< 4 µg/L) (Fig. 6)

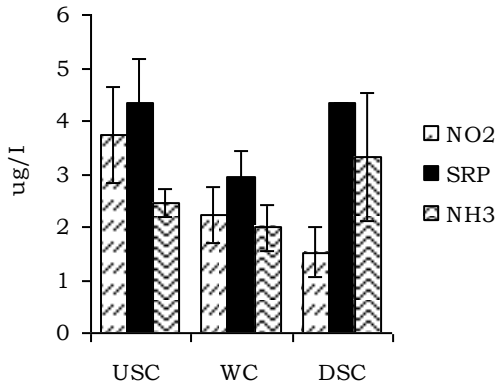


Figure 6. Variation of NO_2-N, SRP and NH_3 across study sites at SON cage fish farm, December 2012

3.2.3 Nitrate

Nitrate nitrogen concentration was high (ca. 30µg/L at WIC compared to NO_2,-N, NH_4-N and SRP (Fig. 7). An increasing trend in NO_3-N occurred towards DSC. The presence of high concentrations of NO_3-N could be attributed to possible presence of un-eaten fish feeds adding up to the other naturally available nutrients in the water.

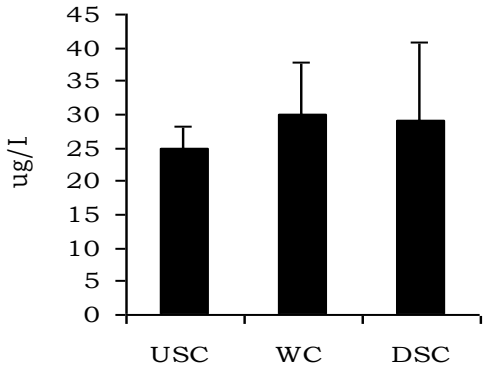


Figure 7. Variation of NO_3-N across study sites at SON cage fish farm, December 2012

3.2.4 Chlorophyll-a and Total suspended solids

Chlorophyll-a was highest at WIC while TSS were higher at DSC and USC and lowest at WIC. The high chlorophyll-a concentration at WIC could be due to the available nutrients in the water column some of which probably comes from the remnants of un-eaten fish feeds. The low concentration of TSS at WIC could be due to sedimentation process induced by the cages resisting the strong wave currents from re-suspending floating particles. There also appears to be an inverse relationship between the TSS and Chll-a (Figure 8).

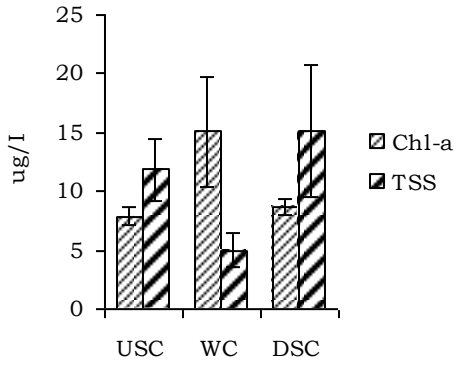


Figure 8. Variation of Chll-a and TSS across study sites at SON cage fish farm, December 2012

3.3 Algal community

Three major taxonomic groups: Blue-green algae (BG), Green algae (G) and Diatoms (D) (Table 4) occurred in all three sites including a fourth group 'others' comprising Dinoflagelates, Cryptophytes and Euglenophytes. The latter rarely occur in the algal community and when present, they contribute very small proportions to the overall algal biomass.

Table 4. Algal species checklist from the three study sites at SON cage fish farm, December 2012.

Blue green algae	**UPS**	**WIC**	**DSC**
Anabaena circinalis	X	X	X
Anabaena compacta			
Anabaena flos aquae			X
Aphanocapsa sp	X	X	X
Aphanocapsa elachista			
Aphanocapsa holistica	X	X	X
Aphanocapsa incerta	X	X	
Aphanocapsa delicatissima	X	X	X
Cyanodycton sp		X	X
Chroococcus dispersus		X	
Chroococcus limnetica	X	X	X
Cylindrospermopsis africana	X	X	X
Cylindrospermopsis cuspis	X	X	
Ceolomoron sp		X	
Puesodoanabaena		X	
P.limnetica	X	X	X
Microsystis aeruginosa		X	X
P.circumreta	X	X	X

P.tallingii	X	X	X
Anabaenopsis tanganyikae	X	X	X
Merismopedia tennussima	X	X	X
Microsystis flos-aquae	X	X	
Microcystis novercerkii			
Merismopedia elagans	X	X	X
Merismopedia glauca	X	X	X
Romeria sp	X		
Green algae			
Scenedesmus perforutus	X	X	X
Scenedesmus maximus			
Scenedesmus acuminatus	X	X	X
Stuarastrum gracile		X	
Ceolastrum lucustris			
Monorophidium tropica	X	X	
Chodatella sp	X	X	
Tetraedon trigonum		X	
Pediastrum simplex	X	X	X
Kirchneriella sp	X	X	X
Diatoms			
Nitzschia acicularis	X	X	X
Nitzschia fonticola	X	X	X
Aulacoseira ambigua			
Navicula Nyassensis	X	X	X
Navicula gastrum			X
Nitzschia nyassensis			X
Synedra cunnigitonii			X

Blue- green algae dominated the algal biomass at all three study sites and showed an increasing trend from USC (ca 1800ug/l), through WIC (ca 2200 ug/l) reaching the highest value (5089.7 ug/l) at DSC (Fig. 9). Blue-green algae of the genera *Anabaena* and *Planktolyngbya* contributed to the observed high biomass and were dominant in all samples. Diatom biomass was much lower (< 1000ug/l) at all three study site while biomass of green algae and 'others' contributed minimal proportions at all the three study sites. *Nitzschia* was notably the dominant genus among the diatom community. The algal biomass trends reported here are comparable to those reported in the June 2012 survey except that highest blue-green algal biomass (25746.24µg/l) occurred at WIC; thus overall, a remarkable decrease appears to have occurred likely due to seasonal changes in the area.

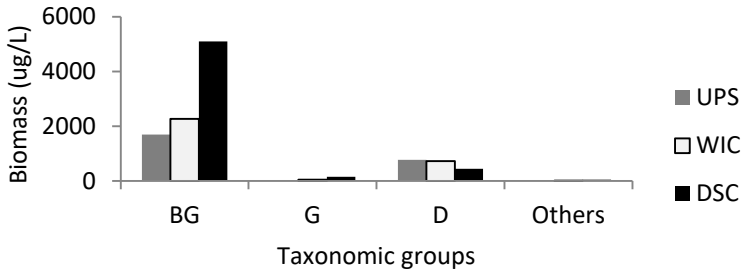


Figure 9. Biomass of algal broad taxonomic groups across study sites at SON cage farm, December 2012

The high biomass of blue-green algae at the downstream/DSC site (Fig. 9) may have resulted from wash down of algal biomass at upstream sites (USC and WIC) by the Nile current. Nutrient generation and subsequently growth of algae can result from un-eaten feeds/remnants and from products of fish excretion at upstream WIC. The composition of the algal communities appear to be stable compared to the previous survey apart from the June 2012 survey where there was an algal bloom dominated by *Anabaena* and such blooms are occur seasonally especially when there is complete mixing which circulates nutrients from the bottom to the water column.

Microcystis and *Anabaena,* which at times form part of the blooms during the mixing period, are associated with a system deficient in nitrogen. This might suggest that most of the time this bay has a nitrogen deficit, which may not necessarily be associated with the presence of cages in the bay. The diatom community which is dominated by *Nitzschia* has remained stable in all the surveys curried out so far compared to the blue- green algae, which changes rapidly in case of any environment stress, which again may not relate to presence of fish cages. Though Mugidde *etal* 1992 reported changes in algal communities in northern part of Lake Victoria, no new species have been found or reported in the recent times of Lake Victoria attributed to environmental stress. Much as blue green algae dominates the composition, especially in shallow near-shore waters, *Anabaena* has an advantage over *Microcystis,* which is the lead producer of toxins in shallow bays of Lake Victoria (Okello et al. 2002 ; Sitoki et al. 2012); a situation that probably makes the fish safe for human consumption.

3.4 Zooplankton community

3.4.1 Species richness and distribution patterns

The combined zooplankton species number varied from 10 to 17 across the three transects. There was only a narrow difference in total species number between the three transects. Copepod species numbers appeared to be nearly evenly spread across the three sampling sites (5-6 species). Rotifera species followed a comparable trend but with a minor depression at WIC while cladocerans had a uniform spread (2 species) across the three sites (Fig. 10). Total species number at the three study sites showed the least number of species at WIC (Fig. 11). The observed trends of species richness are comparable to those recorded during the first semi-

annual survey in June 2012 except that species numbers of the three broad taxonomic groups were lower in the December 2012 survey.

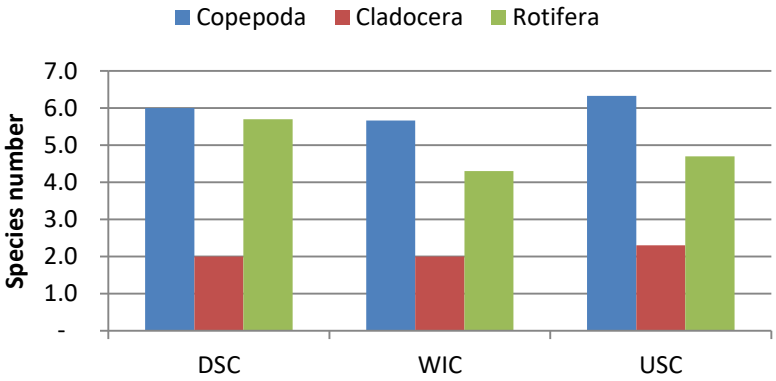


Figure 10. Species richness for the broad zooplankton taxonomic groups at the three study sites, at SON cage fish farm, December 2012

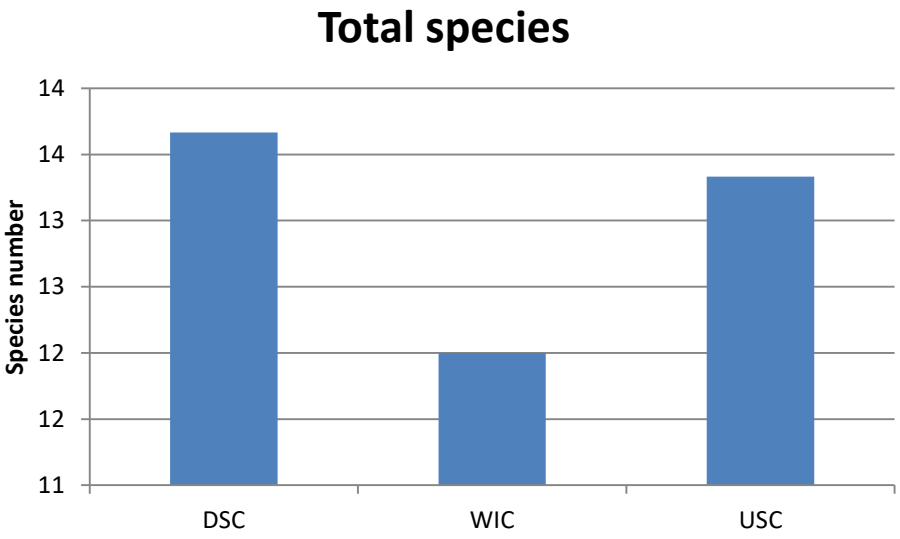


Figure 11. Combined species richness of zooplankton at the three study sites at SON cage fish farm, December 2012.

The commonest and more dominant species were copepods: *Tropocyclops tenellus*, *Thermocyclops neglectus, Thermocyclops emini, Thermodiaptomus galeboides* and in addition, cyclopoid copepodites and nauplius larvae (Table 5). The current results of copepods exhibit similar trends of distribution and abundance to that of the previous survey of the first semi-annual survey of June 2012, which mostly exhibited densities of >10,000 ind.m^{-2} with 100% occurrence. The rare copepods included *Mesocyclops* sp. and *Thermocyclops incisus* with most densities of <1000 ind.m^{-2}. All cladoceran species were rare and less than 1000 ind. m^{-2} except *Diaphnosoma excisum* and *Moina micrura* (> 1000 ind.m^{-2}) at USC (Table 1). Synchaeta sp. were

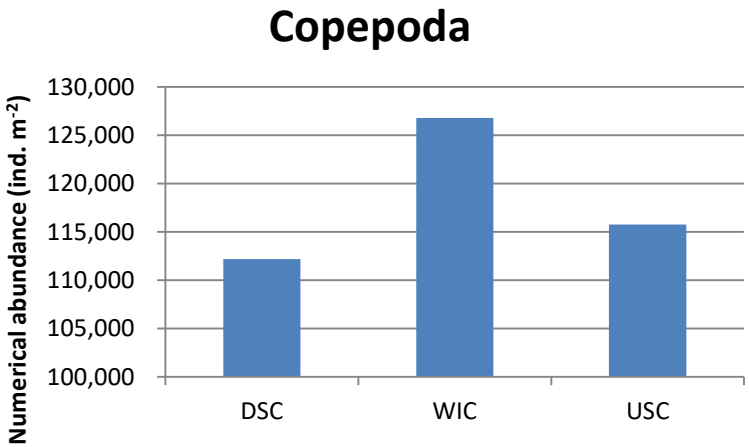
the more abundant rotiferan species compared to *Trichocerca cylindrica, Keratella tropica* and *Lacane bulla* that were abundant in the June 2012 survey. The overall depression of zooplankton species numbers at WIC (Figure 11) may suggest signs of negative impacts on the zooplankton community although the possibility of random occurrence may not be ruled out.

Table 5: Zooplankton species checklist, temporal distribution and abundance inferences across study sites at SON cage fish farm, December 2012
Key: * = <1000, ** = >1000, *** = >10,000 ind. m^{-2}, A= not found

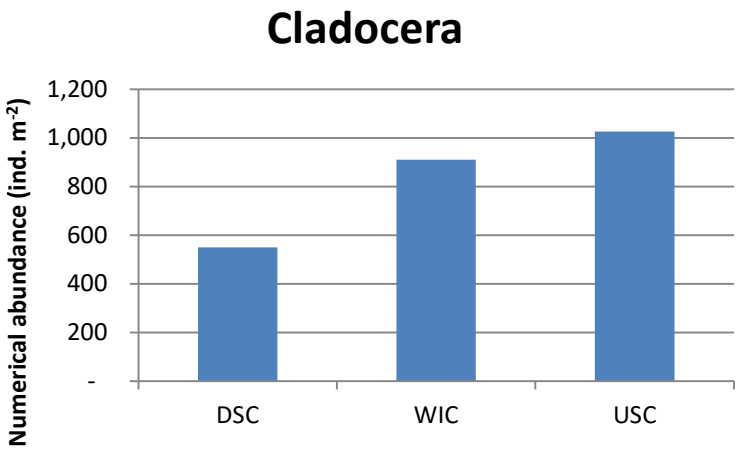
	DSC1	DSC2	DSC3	WIC1	WIC2	WIC3	USC1	USC2	USC3
COPEPODA									
Mesocyclops sp.	*	*	*	*	*	A	A	*	*
Thermocyclops neglectus	**	**	**	**	**	**	*	**	**
Thermocyclops emini	*	**	**	*	*	*	*	**	**
Thermocyclops incisus	A	A	A	A	A	A	*	A	*
Tropocyclops confinnis	A	*	**	**	**	**	**	**	*
Tropocyclops tenellus	**	**	**	**	***	**	**	**	**
Thermodiaptomus galeboides	*	*	**	**	**	*	*	*	*
Harpacticoida	A	*	A	A	A	A	A	A	A
Calanoid copepodites	A	**	**	**	**	**	**	**	**
Cyclopoid copepodites	***	***	***	***	***	***	***	***	***
Nauplius larvae	***	***	***	***	***	***	***	***	***
CLADOCERA									
Bosmina longirostris	*	A	A	A	A	A	*	A	A
Ceriodaphnia cornuta	A	*	*	*	*	*	A	*	*
Diaphanosoma excisum	*	*	A	A	*	*	*	*	*
Daphnia lumholtzi (helm.)	A	*	A	A	A	A	A	*	A

Moina micrura	A	A	A	*	A	A	A	A	A
ROTIFERA									
Brachionus angularis	*	*	A	*	A	A	*	A	A
Brachionus calyciflorus	A	A	A	A	A	*	*	A	A
Brachionus falcatus	A	A	A	*	A	A	*	A	*
Brachionus forficula	A	*	A	A	A	A	*	A	A
Euclanis sp.	*	*	*	A	*	*	*	A	A
Filinia longiseta	A	*	A	A	A	A	A	A	A
Filinia opoliensis	*	A	A	A	A	A	A	A	A
Hexarthra sp	A	A	*	A	A	A	A	A	A
Keratella tropica	**	*	A	A	A	A	*	*	*
Lecane bulla	*	*		*	*	*	*	A	*
Synchaeta sp.	*	*	*	*	**	*	**	*	**
Trichocerca cylindrica	*	A	A	*	A	*	A	A	A
Total species number	**14**	**17**	**10**	**13**	**10**	**13**	**16**	**11**	**13**

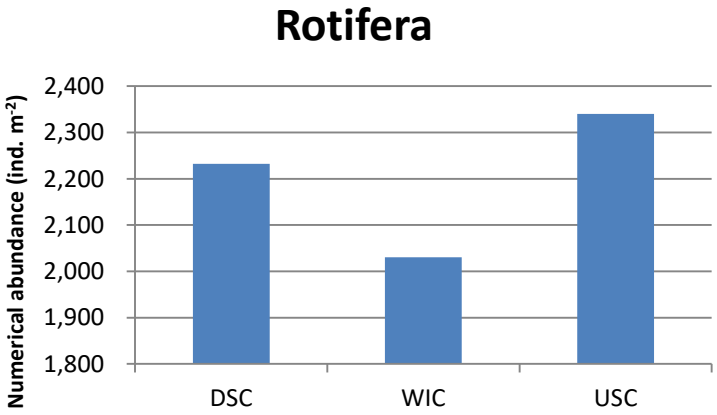
Besides being the most frequently encountered taxon, Copepoda were also the more numerically abundant group in all transects (Fig. 12a-c).



12a.



12b.



12c.

Figure 12a-c. Estimates of numerical abundance for Copepoda **(a),** Cladocera **(b)** and Rotifera **(c)** at the three study sites at SON fish farm, December 2012.
Notice the difference in the vertical scales.

Copepod densities ranged between 112,100 at DSC and 126,700 ind. m^{-2} at WIC while Cladocera ranged between 550 at USC and 1000 ind.m^{-2} at DSC. Rotiferan densities were lowest at WIC 2000 ind. m^{-2} and somewhat higher at DSC 2200 ind. m^{-2} and 2300 ind. m^{-2} at USC.

The December 2012 trends is zooplankton species richness are generally comparable to those of June 2012 except that there appeared to be a substantial decline in the number of cladoceran species from 5 to 2. Subsequent field collections will establish the consistency of this observation. The numerical abundance values for December 2012 survey are much lower than those recorded in the June 2012 for all three sites. This might be related to seasonal variations in zooplankton numerical abundance in Lake Victoria which has been observed to reach annual peak values a round May-June period (Mwebaza-Ndawula et al. 2003).

This time round, species richness was lowest at WIC but density estimates were highest at this site (Figs.11 &13). There is a concentration of the fish cages at this and the site is likely to be affected by excess non-eaten fish feeds, if any, as well as products of fish excretion (i.e. high ammonia and nitrite; Pace, 1986, Zanatta et al., 2010) and defecation all of which may contribute to enhanced localised fertility conditions, especially in cases where water movements are not strong enough to wash away such materials. Eutrophic conditions in freshwater bodies commonly result in changes of phytoplankton productivity (algal blooms), fluctuations in pH, dissolved oxygen and conductivity levels, and a general decrease in aquatic biodiversity (Sekiranda et al., 2004, Tallberg et al., 1999, Cottenie et al., 2003, Hecky, 1993, Mazumder, 1994, Mugidde, 1993, Verschuren et al., 2002, Lungayia et al., 2001, Mavuti and Litterick, 1991). Such changes may be associated with structural changes in the food web and may affect the quality and quantity of phytoplankton composition and biomass (Dodson et al., 2000, Mugidde, 2004, Mwebaza-Ndawula, 1994, Tallberg et al., 1999, Cottingham, 1999), which may in turn alter zooplankton community structure largely because most zooplankton species are algal herbivores (Gosselain et al., 1998, Gowen et al., 1992, Steiner, 2003). This may be part of the explanation for the lower species richness at WIC, although the differences between sites appear not to be high magnitude. It would certainly be interesting to follow up this observation with further field study.

3.4.2 Zooplankton abundance estimates across study sites

The 'within cages' transect registered the highest average numerical abundance (129,700 ind m^{-2}) in comparison to 'upstream of cages' USC (199,100 ind. m^{-2}) and 'downstream of cages DSC (114,900 ind. m^{-2}) (Fig. 13). It was noted that these abundance figures were an order of magnitude lower than those recorded in the June 2012 survey but the trend across the three study sites remained generally the same and comparable; with highest values at WIC relative to USC and DSC. The density peak at WIC is at variance with a slight depression observed in the June 2012, although the latter values were higher.

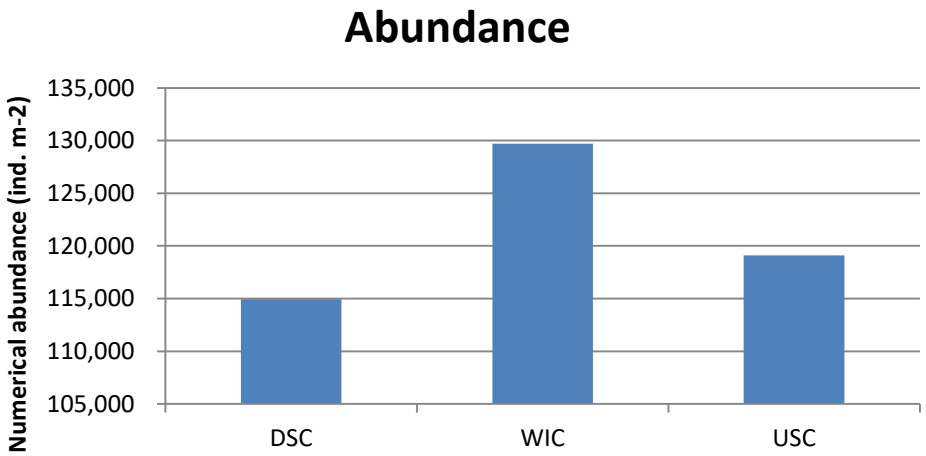


Figure 13. Overall numerical abundance estimates for the three study sites at SON cage fish farm, December 2012

3.5 Macro-benthic community

3.5.1 Composition

The community was represented by mollusks (2 taxa: Bivalves and Gastropoda), Ephemeroptera, Diptera and Annelida, each containing several species and/or small taxonomic groups/taxa (Table 6). Bivalvia contained 4 species; Gastropoda 5 species; Ephemeroptera1 species; Diptera 5 species and 2 other small taxa; Annelida 2 small taxa. Eight (8) species were recovered at USC; 12 at WIC and 19 at DSC; thus representing an increasing trend from USC through WIC to DSC. A number of macro-benthic species such as *B. unicolor* and *M. tuberculata* (Gastropoda/mollusks); *Ablabesmyia* sp., *Chironomus* sp., *Tanypus* sp. and *Chaoborus* sp. (Diptera) were common to all sites. On the other hand, a number of taxa including *Byssanodonta parasitica (*Bivalvia*), Povilla adusta (*Ephemeroptera), *Tanytarsus* sp. (Diptera) and Hirudinea (Annelida) were rare, occurring only once.

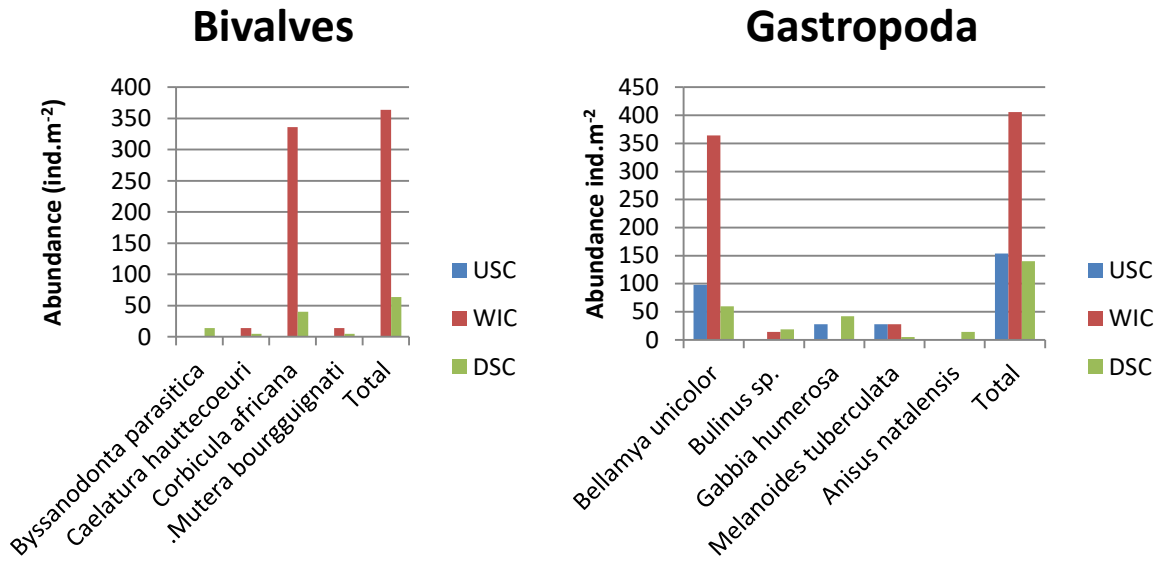
Table 6. Occurrence of macro-benthic taxa at the three study sites at SON fish farm, December 2012

	USC	WIC	DSC
Bivalvia			
Byssanodonta parasitica			P
Caelatura hauttecoeuri		P	P
Corbicula africana		P	P
Mutera . bourgguignati		P	P
Gastropoda			
Bellamya unicolor	P	P	P
Bulinus sp.		P	P
Gabbia humerosa	P		P
Melanoides tuberculata	P	P	P
Anisus natalensis			P
Ephemeroptera			
Povilla adusta			P
Diptera			
Ablabesmyia sp	P	P	P
Chironomus sp.	P	P	P
Tanypus sp	**P**	**P**	**P**
Tanytarsus sp.			P
Chironominea	P		P
Ceratopogonidea		P	P

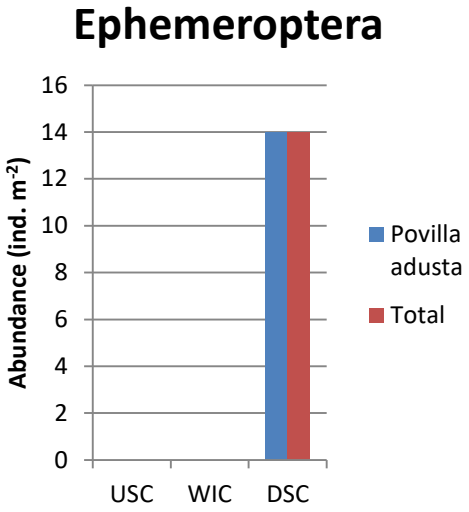
Chaoborus sp.	P	P	P
Annelida			
Hirudinea			P
Oligochaetes		P	P
Total No. of taxa	8	12	19

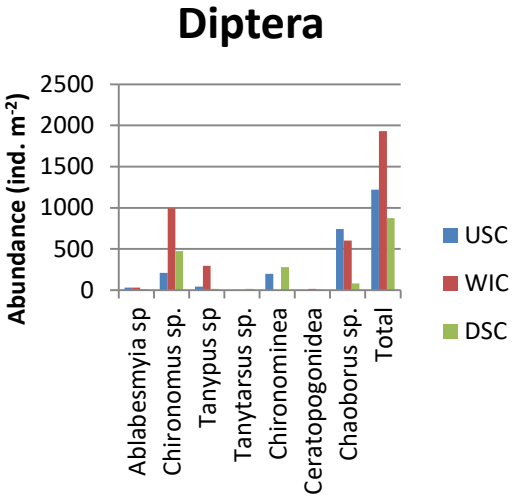
3.5.2 Abundance patterns of macro-benthos

Three (3) macro-benthic groups were recovered in relatively high abundance at the fish cage site (WIC). These were *C. africana* (Bivalves), *B.unicolor* (Gastropoda) (Fig. 14a); *Chironomus* sp and *Chaoborus* sp. (Diptera) (Fig. 14b) and Oligochaetes (Annelida) (Fig. 14c). Other additional taxa especially of Gastropoda and Diptera were also represented at other sites (USC and DSC), albeit in smaller proportions. Notably, Ephemeroptera occurred only once and in low proportions (14 ind. m^{-2}) at DSC. Oligochaeta also occurred only once at WIC but in relatively high density (280 ind. m^{-2}).

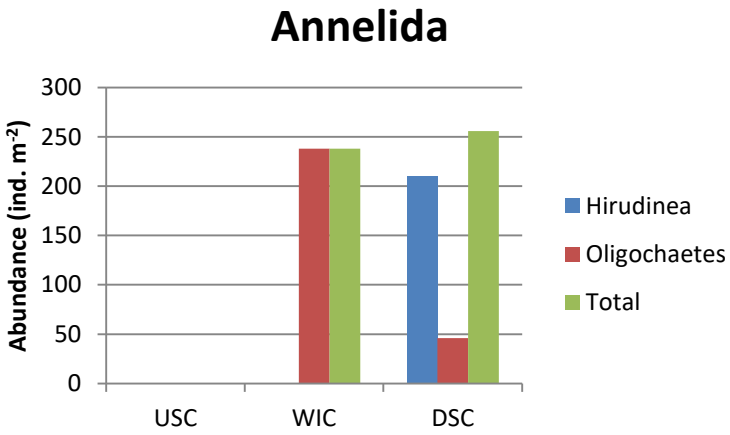


14a

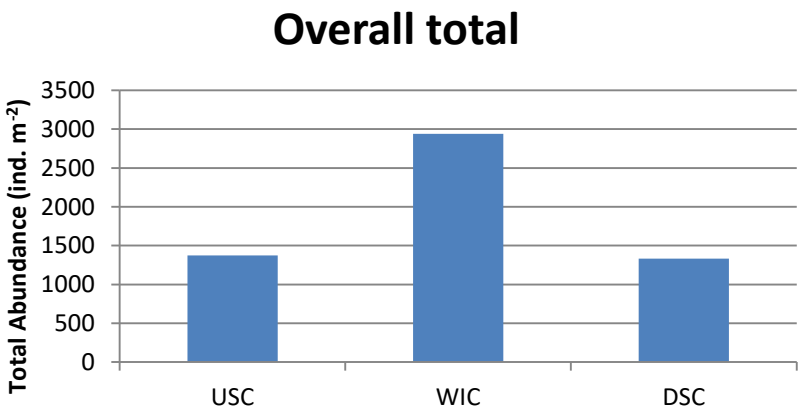




14b



14c



14d

Figure 14a-d. Estimates of numerical abundance of macro-benthic broad taxonomic groups at SON cage fish farm, December 2012. **Notice difference in vertical scales.**

Overall, WIC not only supported more macro-benthic taxa but these were also in higher abundance (2900 ind.m^{-2}) (Fig. 14d).

3.5.3 Occurrence and abundance of the EPTs

This time round, only one member of the EPTs, Ephemeroptera, was recovered at DSC and occurred in very small amount (Fig. 14b).

In summary, the composition of macro-benthos in the current survey (December 2012) fell short of Trichoptera, a common EPT member in the previous surveys. Nonetheless, other macro-benthic groups such as Bivalvia, Gastropoda, Ephemeroptera, Diptera, Hirudinea and Oligochaeta were present. Despite a general rise in the densities of most groups in comparison with the June 2012 results, the contribution of dipterans especially chironomids and chaoborids (Fig. 14b) was markedly high particularly at WIC site while gastropods densities declined considerably in the same area. The taxonomic diversity of macro-benthos, however, fell within the range of past surveys in general. Non-occurrence of EPT members in samples from WIC, reported in all the preceding reports, continued in the present survey.

3.5.4 Bottom type description

The sediment type at the three study sites did not differ from the observations of the previous results (Table 7) although taxonomic diversity and densities of macro-benthos (particularly the latter) revealed variation probably due to seasonal changes in some environmental factors.

Table 7: Bottom type description at SON fish farm, December 2012.

	USC	**WIC**	**DSC**
General bottom type	Gravel/ stony sand	Silt with some sand, decomposed organic material and shells.	Bare / rocky (little filamentous algae got)

3.6 Fish community

3.6.1 Background

Ecological impacts of cage fish farming on fresh water ecosystems are generally lacking but several investigations have accrued to marine ecosystems (Naylor *et al*., 2000). Thus, impacts upon wild fish stock close to culture cages are relatively unknown. The fish rearing operations at SON fish farm involve keeping Nile tilapia fish in cages under high stocking densities and feeding them on artificial feeds. Napoleon Gulf being a shallow bay at the headwaters of the River Nile in Lake Victoria, harbors a wide variety of wild fish species that are cherished by riparian human populations. The wild fishes living close to cages are bound to be affected by activities associated with this method of fish farming. Cage fish farming is likely to affect the presence, abundance, and diet of organisms in the vicinity of the farm (Carss, 1990; Dempster *et al.,* 2002). Floating structures including cages may act as Fish Attracting Devices (FADs) as

most pelagic fishes are known to be strongly attracted to floating objects (Freon and Dagorn, 2000; Castro *et al.,* 2002). Attraction to cage sites may be largely due to plenty of food available for the cultured fishes (Bjordal and Skar, 1992). As such, other ecological interactions between cultured and wild fish may be possible. Wild fish may be instrumental in cleaning the environment close to the cages through consumption of excess un-eaten food left by culture fishes. Caged fish under crowded conditions is vulnerable to water-borne diseases and could infect wild fish or vice versa. While diseases breaking out among cultured fishes may be controlled through treatment, diseases in wild fishes stocks may spread unabated and in severe cases can affect yields of a capture fishery.

3.6.2 Fish Catch composition

A total of 12 fish species: 7 haplochromines (Nkejje) and 5 non-haplochromines), belonging to 5 families were recorded in the vicinity of the cages (Table 8). *Synodontis afrofischeri* dominated the fish catches by numbers, contributing 34.9% of all the fishes caught while *Synodontis victoriae* was the dominant species by weight with 37.2%; followed by the Nile perch (*Lates niloticus*) with 32.8%. Other fish species caught in order of numerical importance were Haplochromines (Nkejje) 21.8%, *Mormyrus kannume* (Elephant snout fish: Kasulubana) 0.9% and *Protopterus aethiopicus* (Lungfish) 0.2%. Lowest fish diversity (4 species) was observed at upstream of cages/USC while the highest diversity (9 species) was recorded downstream of cages/DSC and 7 species at within cages/WIC area. Fish abundance was highest within the cages/WIC with 54.3% and lowest upstream/USC with 7.6%.

Table 8. Catch rates (numbers) of fish species from SON cage fish farm, December 2012 compared with previous surveys (2011 & June 2012)

Sampling period			**Q1**	**Q2**	**Q3**	**Q4**	**H1**	**H2**
Date of sampling			Feb. 2011	May. 2011	Sep. 2011	Nov. 2011	Jun. 2012	Dec. 2012
Season			Dry	Wet	Wet	Wet	Wet	Wet
Family	**Species**	**Site**						
Protopteridae	*Protopterus aethiopicus*	USC	0	0	0	0	0	0
		WIC	0	0	0	0	0	0
		DSC	0	0	0	0	0	0.08
		All	0	0	0	0	0	0.03
Mormyridae	*Mormyrus kannume*	USC	0.2	0.08	0.1	0	0	0.15
		WIC	0	0	0	0.2	0.15	0.15
		DSC	0	0	0	0.2	0	0
		All	0.1	0.03	0.03	0.2	0.05	0.10
Characidae	*Brycinus jacksoni*	USC	0	0	0	0	0	0

		WIC	0	0	0	0	0	0
		DSC	0	0.75	0	0	0.25	0
		All	0	0.25	0	0	0.08	0
Clariidae	*Clarias alluaudi*	USC	0	0	0	0	0	0
		WIC	0	0	0.8	0	0	0
		DSC	0	0	0	0	0	0
		All	0	0	0.3	0	0	0
	Clarias gariepinus	USC	0	0	0.1	0	0	0
		WIC	0	0	0	0	0	0
		DSC	0	0	0	0.2	0.13	0
		All	0	0	0.03	0.1	0.03	0
Mochokidae	*Synodontis victoriae*	USC	0.3	0	0	0	0	5.0
		WIC	0	0	0	0	0	17.75
		DSC	0	0	0	0	0	11.5
		All	0.1	0	0	0	0	11.42
	Synodontis afrofischeri	USC	0.3	0	0	0.5	0	2.75
		WIC	0	0	0	1203	0	38.25
		DSC	0	0	0	0	0	0.25
		All	0.1	0	0	5.0	0	13.75
Centropomidae	*Lates niloticus*	USC	0.5	0.08	0.3	0.3	0.85	0.23
		WIC	0.2	0.31	0.1	0.2	1.54	1.92
		DSC	0.1	0.38	0	0.2	0.23	2.69
		All	0.2	0.26	0.1	0.2	0.87	1.62
Cichlidae	*Tilapia zillii*	USC	0.4	0	0	0	0	0
		WIC	0	0	0.4	0	0	0
		DSC	0.1	0	0.1	0	0	0
		All	0.2	0	0.2	0	0	0
	Oreochromis niloticus	USC	0	0.08	0	0	0	0
		WIC	0	0.15	0.5	0	0	0
		DSC	0.1	0.08	0.1	0	0	0
		All	0.03	0.1	0.2	0	0	0
	Haplochromines	USC	7.3	0.75	2.3	9.5	18.5	0.0
		WIC	7	1.5	58.5	1.8	0.5	1.50

		DSC	20.3	12.25	16.5	8.5	2.25	24.25
		All	11.5	4.83	25.8	6.0	7.07	8.58
Overall Rates		USC	3.3	0.5	1.2	2.1	6.54	2.77
		WIC	2.3	0.9	19.1	4.6	1.85	19.77
		DSC	6.5	4.5	5.2	2.9	1.08	13.85
		All	4	2	8.5	3.3	3.15	12.13
No of species recovered		USC	12	5	4	3	9	4
		WIC	5	4	5	4	4	7
		DSC	8	8	3	3	9	9
		All	16	11	7	12	15	12

3.6.3 Haplochromines

The 7 species of haplochromines recovered during the December, 2012 sampling belonged to 7 different genera (Table 8). Highest haplochromine diversity (5 species) was recorded from downstream of cages/DSC; 3 species were recovered from the within cages/WIC site while no haplochromines were recovered from the upstream of the cage/USC site. As in the previous surveys, the most abundant haplochromine during the December sampling was *Astatotilapia* (80.6%) followed by *Psammochromis sp (13.6%), Paralabidochromis, Ptyochromis* and *Xysitchromis* contributed 0.97% each.

Haplochromine species such as *Ptyochromis* are associated with rocky or hard bottom substrates which is a common habitat type at Bugungu area where the SON cage fish farming operations are located.

3.6. 4 Catch rates / biomass estimates

As a measure of standing biomass, catch rates i.e. catch per net per night was used to indicate relative abundance of fish species. To analyze gillnet performance; the nets and thus fish species were grouped into three categories. Category (A) consisted of fishes that grow to a small adult size and are caught by nets of up to 2.5" stretched mesh. Category (B) consisted of fish that could be retained by nets of up to 4.5" while category (C) was of large fish species capable of being caught in all the nets set. By numbers, catch rates were highest at the within cages/WIC site with 19.8 fish per net (Table 8) and by weight it was the same site as with 1161.1g per net (Table 9). Overall mean catch rates for the December 2012 survey were 12.13

and 842.4g compared to 3.15fish and 791.6g per net during the June 2012 survey. Thus more fish were recovered during this season compared to the previous sampling period/season.

Table 9. Catch rates by weight (g) of fish caught in SON fish farm, December, 2012 compared to data from previous surveys (2011 & June 2012).

Sampling period			**Q1**	**Q2**	**Q3**	**Q4**	**H1**	**H2**
Date of sampling			Feb. 2011	May. 2011	Sep. 2011	Nov. 2011	Jun. 2012	Dec. 2012
Season			Dry	Wet	Wet	Wet	Wet	Wet
Family	Species	Site						
Protopteridae	*Protopterus aethiopicus*	USC	0	0	0	0	0	0
		WIC	0	0	0	0	0	0
		DSC	0	0	0	0	0	105.7
		All	0	0	0	0	0	35.2
Mormyridae	*Mormyrus kannume*	USC	32.3	61.1	6	0	0	92.0
		WIC	0	0	0	172	53.1	10.3
		DSC	0	0	0	0		0.0
		All	10.8	20.4	2	60	17.7	34.1
Characidae	*Brycinus jacksoni*	USC	0	0	0	0	0	0
		WIC	0	0	0	0	15.5	0
		DSC	0	34.5	0	0	0	0
		All	0	11.5	0	0	5.2	0
Clariidae	*Clarias alluaudi*	USC	0	0	0	0	0	0
		WIC	0	0	17	0	0	0
		DSC	0	0	0	0	0	0
		All	0	0	6	0	0	0
	Clarias gariepinus	USC	0	0	147	0	0	0
		WIC	0	0	0	0	0	0
		DSC	0	0	0	308	531	0
		All	0	0	49	108	109.0	0
Mochokidae	*Synodontis afrofischeri*	USC	5	0	0	26	0	166.5
		WIC	0	0	0	597	0	1286
		DSC	0	0	0	0	0	7.5
		All	1.7	0	0	244	0	486.7
	Synodontis victoriae	USC	21.5	0	0	0	0	475
		WIC	0	0	0	0	0	1271.5
		DSC	0	0	0	0	0	1308.5
		All	7.2	0	0	0	0	1018
Centropomidae	*Lates niloticus*	USC	118.9	1.38	138	2	198.5	59.6

		WIC	17.8	126.3	1	5	1428.5	357.7
		DSC	3.7	8.0	0	8	266.9	410.6
		All	46.8	45.2	46	5	631.3	276
Cichlidae	*Tilapia zillii*	USC	38.3	0	0	0	0	0
		WIC	0	0	3	0	0	0
		DSC	2.3	0	12	0	0	0
		All	13.5	0	5	0	0	0
	Oreochromis niloticus	USC	0	5.2	0	0	0	0
		WIC	0	9.9	79	0	0	0
		DSC	0.9	0.5	16	0	0	0
		All	0.3	5.2	32	0	0	0
	Haplochromines	USC	96.5	19.0	35	9	264	0.0
		WIC	70	10.5	520	71	8.5	20.0
		DSC	411	243.5	345	90	40.5	311.5
		All	192.5	91.0	300	66	104.4	110.5
Overall Rates		USC	212.6	73.5	302	8	279.7	348.9
		WIC	39.4	139.4	246	382	1484.2	1161.1
		DSC	132.5	94.0	129	343	611.1	1017.1
		All	128.2	102.3	226	257	791.6	842.4
No of species recovered		USC	12	5	4	3	9	4
		WIC	5	4	5	4	4	7
		DSC	8	8	3	3	9	9
		All	16	11	7	12	15	12

Table 10. Catch rates (by numbers) of haplochromine species from SON cage fish farm, December 2012 compared with data from previous (2011 & June 2012)

Sampling period			**Q1**	**Q2**	**Q3**	**Q4**	**H1**	**H2**
Date of sampling			Feb. 2011	May. 2011	Sep. 2011	Nov. 2011	Jun. 2012	Dec. 2012
Season			Dry	Wet	Wet	Wet	Wet	
Genus	**Species**	**Site**						
Astatoreochromis	*A. alluaudi*	USC	0	0	0	0	0	0
		WIC	0	0	0	1.7	0	0
		DSC	1.5	0	0.6	0	0	0.25
		All sites	1.5	0	0.6	1.7	0	0.08
Astatotilapia	*A. macrops*	USC					0	0

		WIC					0	0
		DSC					1.2	0
		All sites					1.2	0
	A. martini	USC					0	0
		WIC					0	0
		DSC					2.4	0
		All sites					2.4	0
	A. pallida	USC					28.2	0
		WIC					0	0
		DSC					2.4	0
		All sites					30.6	0
	A. "thick lip"	USC	3.6	0	0	0	0	0
		WIC		0	0	0	0	0
		DSC		0	0	0	0	0
		All sites	3.6	0	0	0	0	0
	A. "pink anal"	USC		0	0	0	0	0
		WIC		0	0	0	0	0
		DSC		60.3	0	0	0	0
		All sites		60.3	0	0	0	0
	Astatotilapia sp	USC	12.3	0	0.9	28.3	9.4	0
		WIC	6.5	8.6	68.3	1.7	0	0.75
		DSC	42.3	15.5	5.1	46.7	0	20
		All sites	60.9	24.1	74.3	76.7	9.4	6.9
Harpagochromis	*H. guiarti*	USC					2.4	0
		WIC					0	0
		DSC					1.2	0
		All sites					3.5	0
Lipochromis	*L. parvidens*	USC	0.7	0	0	0	0	0
		WIC	0	0	0	0	0	0
		DSC	0	1.7	0	0	0	0
		All sites	0.7	1.7	0	0	0	0
Lithochromis	*Lithochromis sp*	USC	0	0	0	0	0	0
		WIC	0	1.7	0	0	0	0
		DSC	0	0	0	0	0	0
		All sites	0	1.7	0	0	0	0
Mbipia	*M."blue"*	USC	0.7	0	0	0	0	0
		WIC	0	0	0	0	0	0
		DSC	0	0	0	0	0	0
		All sites	0.7	0	0	0	0	0

	M. mbipi	USC	0	0	1.8	0	10.6	0
		WIC	0	0	0	1.7	1.2	0
		DSC	0	0	0	0	0	0
		All sites	0	0	1.8	1.7	11.8	0
Paralabidochromis	*P. "blackpara"*	USC	1.5	3.4	0	0	10.6	0
		WIC	0.7	0	2.1	1.7	0	0.5
		DSC	8.7	3.4	13.6	1.7	1.2	0
		All sites	10.9	6.9	15.7	3.3	11.8	0.17
	P. victoriae	USC	0	0	0	0	0	0
		WIC	0	0	0.3	0	0	0
		DSC	0	0	0	0	0	0
		All sites	0	0	0.3	0	0	0
Psammochromis	*P. riponianus*	USC	0	1.7	0	3.3	2.4	0
		WIC	2.2	0	0	0	0	0
		DSC	4.4	0	0.3	8.3	2.4	3.5
		All sites	6.5	1.7	0.3	11.7	4.7	1.17
Ptyochromis	*P. sauvagei*	USC	0	0	0	0	22.4	0
		WIC	0	0	0	0	0	0
		DSC	2.2	0	0	0	0	0.25
		All sites	2.2	0	0	0	22.4	0.08
	P. xenognathus	USC					1.2	0
		WIC					0	0
		DSC					0	0
		All sites					1.2	0
Pundamilia	*Pundamilia sp*	USC	0.7	0	0	0		0
		WIC	10.9	0	0	0		0.25
		DSC	0	0	0	0		0
		All sites	11.6	0	0	0		0.08
	P. macrocephala	USC	1.5	0	0	0	0	0
		WIC	0	0	0	0	1.2	0
		DSC	0	0	0	0	0	0
		All sites	1.5	0	0	0	1.2	0
Xystichromis	*X. "earthquake"*	USC	0	0	0	0		0
		WIC	0	0	0	0		0
		DSC	0	3.4	0	0		0
		All sites	0	3.4	0	0		0
	X. phytophagus	USC	0	0	0	0		0
		WIC	0	0	0	0		0
		DSC	0	0	0.3	0		0.25

		All sites	0	0	0.3	0		0.08
Overall Contribution		USC	21	5.2	4.5	31.7	87.1	0
		WIC	20.3	10.3	74.9	11.7	2.4	5.8
		DSC	58.7	84.5	20.5	56.7	10.6	94.2
		All sites	100	100	100	100	100	100
No of species recovered		USC	7	2	2	2	8	0
		WIC	4	2	3	7	2	3
		DSC	5	5	5	3	6	5
		All sites	10	7	7	8	11	7

3.4.4 Biology of common fish species

Basic biology of common fish species caught from the cage area in all quarters sampled in 2011, during the first and second halves of 2012 is summarized in Table 11. Other than *Synodontis afrofischeri* and *S. victoria,* the rest of fish species were in low numbers.

Table 11. Basic biological parameters of fish species caught SON Fish in December 2012 compared to data from previous (2011 & June 2012) surveys.

Sampling period	Parameter	Year 2011	1st Half 2012	2nd Half 2012
Date of sampling		Feb, May, Sep, Nov	June 2012	Dec 2012
Season		1 Dry & 3 wet	Wet	Wet
Species				
Protopterus aethiopicus	Size range (cm)	0	0	72.8
	% mature	0	0	Mature
	Main food type	0	0	Mollusks
	Parasites found	0	0	Nil
	Number examined	0	0	1
Clarias alluaudi	Size range (cm)	13.6 – 15.1	0	0
	% mature	100	0	0
	Main food type	IR, FR	0	0
	Parasites found	Nil	0	0
	Number examined	3	0	0
Clarias gariepinus	Size range (cm)	58 - 51	83	0
	% mature	100	Mature	0
	Main food type	ODT, FR	ODT, OSTRAC, FR,	0
	Parasites found	Nil	0	0

	Number examined	2	1	0
Lates niloticus	Size range (cm)	9 - 69	9 - 56	10.2 – 45.5
	% mature	17	2	
	Main food type	Haps	Haps, Ephem, Mollusk	Haps, Caridina
	Parasites found	Nil	Nil	Nil
	Number examined	31	41	48
Brycinus jacksoni	Size range (cm)	13 - 15	14.1	0
	% mature	All mature	Mature	0
	Main food type	ODT, IR	White ants	0
	Parasites found	Nil	Nil	0
	Number examined	3	1	0
Haplochromines	Size range (cm)	6.7 – 18.6	7.9 – 13.0	8 – 14.5
	% mature	83	87	100
	Main food type	Chiro Larvae	Povilla	Povilla,
	Parasites found (% infection)	Nematode 6	Nematode 6%	Nematode 10%
	No examined	166	70	28
Tilapia zillii	Size range (cm)	7 - 20	0	0
	% mature	50	0	0
	Main food type	All empty	0	0
	Parasites found	0	0	0
	No examined	8	0	0
Mormyrus kannume	Size range (cm)	19 - 61	18 - 39	18.5 – 47.2
	% mature	46	50	25
	Main food type	Povilla, IR	Povilla, Chiro L	Chiro L, Povilla
	Parasites found	Nil	Nil	Nil
	No examined	7	2	4
Oreochromis niloticus	Size range (cm)	7 - 28	0	0
	% mature	All immature	0	0
	Main food type	All Empty	0	0
	Parasites found	Nil	0	0
	No examined	13	0	0
Synodontis afrofischeri	Size range (cm)	9.2 -14.5	0	9.2 – 14.8
	% Mature	All mature	0	All mature
	Main food type	Mollusks	0	Chiro L, Moll
	Parasites found	Nematode 7%	0	Cestode 3%
	No examined	16	0	32

Synodontis victoriae	Size range (cm)	18	0	10.2 – 22.1
	% mature	Mature	0	96%
	Main food type	Povilla	0	Mollusks, Povilla, Chiro L
	Parasites found	Nil	0	Nil
	No examined	1	0	60

Fish catch rates by weight were higher than the mean rates calculated for the first half (June 2012) survey (842 cf 792g/net/night respectively). This modest increase was largely due to abundant *Synodontis* species caught during the current (December 2012) survey.

Although on a number of occasions the downstream station (DSC) has had more fish, this time round, there was a shift to the within cages (WIC) site. Only one fish stomach/gut belonging to a specimen of *Synodontis afrofischeri* contained artificial feeds. It may be presumed that remnants of the artificial feeds are swept by currents to the downstream site (DSC) and this may probably attracts fish in this area.

3.4.5 Fish community Summary

- A total of 12 fish species were recorded in the vicinity of the cages
- Fish species diversity was highest downstream/DSC followed by within cages/WIC but lowest upstream cages/USC and catch rates were highest at the within cages/WIC while least catch rates were realized upstream of cages/USC area as in the June 2012 survey.
- Fish abundance and catch rates were highest at WIC
- Fish catch rates were higher than mean catches calculated for the June 2012 survey.
- The diet of fishes encountered consisted of known natural foods of the species caught. Remnants of food fed to the cage fish were only recovered from one specimen of *Synodontis afrofischeri*.
- No serious infection by fish parasites was noticed on the fishes caught. A few common nematodes were occasionally encountered in the guts of some haplochromines and *Synodontis* species.

4.0 General Conclusions

1. In general, water quality conditions at the cage farm has not shown much change from that reported in the 2011 surveys, which indicated good water environment for aquatic biota in general.

2. Current levels of all determined nutrient parameters are well below those considered toxic to fish and other aquatic organisms. It is however to be noted that near-shore water quality in Lake Victoria in general tends towards eutrophic (over-fertilized) conditions compared to offshore water and this has implications on respective water quality conditions and aquatic productivity.

3. The presence of *Microcystis* and *Anabaena* both of which are the nitrogen fixers may indicate that the system suffers nitrogen deficit at all times in the year with a peak during algal blooms.

4. Some species of blue-green algae may pose a threat to aquatic biota if present in high concentrations (blooms) because of their potential to produce toxins and may clog gills of fish thereby causing suffocation. However, the concentrations so far recorded are below the WHO benchmark.

5. Persistent depressed species richness in the transect/site with cages (WIC) may point to possible negative impacts on zooplankton community by the cage culture operations but further field study is necessary to confirm these observations.

6. Observed high TN, NO3-N and chlorophyll-a values, high zooplankton, macro-benthos, fish abundance and catch rates at WIC site provides a strong indication so far of possible impacts (positive!) from cage operations to the water natural environment and biota

7. Current field observations on the fish community indicate that so far there is little or no negative effects from cage fish culture on the wild population of fishes in the area and likely, the Napoleon Gulf at large.

5.0 Recommendations

1. Regular monitoring of key aspects of the water environment need to be sustained in and around the fish cages for the purpose of early detection of any possibility of environment change, which if not mitigated early, may compromise environment quality with consequences to aquatic production and productivity.
2. In the next round of environmental monitoring, there will also be need to relocate at least the USC sample transect as it currently lies in an areas covered by cages due to expansion of the cage area from the time the first surveys were undertaken.
3. As the number of cage units have increased at the SON fish farm since 2011, there has been records (documented in past periodic reports) suggesting possible periodic effects

of fish cage operations to the water environment quality and sections of the aquatic biota especially algae, zooplankton and macro-benthos. It is therefore recommended that the issue cage concentration in any one area should be carefully controlled in order to avert possible deleterious environmental impacts from cage operations that may drastically alter key aspects of the ecology in the areas under fish cage culture.

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