NATIONAL FISHERIES RESOURCES RESEARCH INSTITUTE (NaFIRRI)

Technical Report on the Environmental Monitoring of the Cage Area at the Source of the Nile (SON) Fish Farm for Quarter 1: January-March 2015

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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 have a collaborative arrangement with NaFIRRI to undertake quarterly environment monitoring of the cage site as is mandatory under the NEMA conditions. The monitoring surveys cover selected physical-chemical factors i.e. water column depth, water transparency, water column temperature, dissolved oxygen, pH and conductivity; nutrient status, algal and invertebrate communities (micro-invertebrates/zooplankton and macro-invertebrates/macro-benthos) as well as fish community. The first quarter survey for the calendar year 2015, which is the subject of this report, was undertaken in March 2015. 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.

Depth profiles and water transparency and GPS positions were determined with an Echo sounder, black and white secchi disc and a GPS device respectively. Water column temperature, dissolved oxygen, pH and conductivity were measured in-situ with a CTD. 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 collected with Nansen type plankton net of 0.24m mouth opening and 60µm Nitex mesh. Macro-benthic community was sampled with a Ponar grab of open jaw area, 238cm^2. Invertebrate samples were analyzed 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 established per site. Observations were also made on aspects of the biology and ecology of the fishes caught.

Total depth at the study site was between 2 and 17 metres at DSC and USC respectively. Secchi depth exhibited minimum variation between sites with 1.2 (USC & DSC) and 1.3 (WIC) metres. Turbidity ranged between 1.1 and 12.4 NTU but despite the wide range, this variation is still considered to be low. Dissolved oxygen was high at USC (mean 7.5 ± 0.5 mg/L) but decreased to 6.7 ± 0.01 mg/L at DSC. This range is considered sufficient for aquatic life. Water temperature was lower at USC (27.2 ± 0.32 °C) and was warmest at WC (27.4 ± 0.25 °C). The observed temperature is within the acceptable range for freshwater life. pH was lowest at USC (7.8 ± 0.08) and highest at DSC (8.9 ± 0.0) and was within the optimal range(6 – 9) for cage fish culture. Conductivity was higher at WC (101.3 ± 0.22 µScm^{-1}) compared to USC and DSC. The observed conductivity 99 to 110.0µScm^{-1} was within what is normally observed in Lake Victoria. In general, the foregoing results do not indicate signs of water quality degradation within and around the fish cages at SON.

Soluble reactive phosphorus (SRP) ranged from 0.018mg/l upstream (USC), to 0.022mg/l at (WIC) and 0.023mg/l downstream (DSC). Mean nitrate-nitrogen levels did not vary much in all sampled sites, but indicated a slight increase from 0.043mg/l at DSC, to 0.048mg/l at WIC and 0.051mg/l at USC. Ammonia-nitrogen was generally low at all sampled sites; ranging from 0.009mg/l at DSC, to 0.011mg/l at USC and WIC. Ammonia-nitrogen was generally low at all sampled sites; ranging from 0.009mg/l at DSC, to 0.011mg/l at USC and WIC. Mean TN values were higher upstream (0.05mg/l), declining to 0.022mg/l at WIC and increasing slightly to 0.039mg/l at DSC. Total suspended solids (TSS) increased from 4mg/l at DSC to 6mg/l at WIC

and 7mg/l at USC. Notably, the levels of all measured nutrient parameters above were below those considered toxic to fish. However, SRP levels were less than the normal range (0.1mg to 0.2mg/l) for sustenance of phytoplankton at the base of the aquatic food chain and an important natural food for tilapine fishes.

Four algal groups, (Blue green, Green, Diatoms and Cryptophyte) were found in the three study transects with Blue green algae dominating the biomass and the upstream site, USC having highest biomass. Colonial algae (*Microcystis, Aphanocapsa, Chroococcus, Anabaena, Chroococuss and Merismopedia*, and the filametious alga (*Planktolyngbya*) contributed to the blue green algal community.

The zooplankton community was constituted by copepods, cladocerans and rotifers as observed in all previous surveys. Copepod species number ranged between 4 and 7, cladocerans 0 and 5 and rotifers 3 and 12. The commonest species (> 89%) were mostly copepods: *Tropocyclops tenellus, Tropocyclops tenellus, Thermodiaptomus galeboides, Thermocyclops neglectus, Mesocyclops* sp. and rotifers: *Keratella tropica, Trichocerca cylindrica and Lacane bulla*. Two upstream sites (USC2 and USC3) registered the highest numerical abundance i.e. 4,451,917 and 4,529,600ind. m^{-2} respectively.

A total of 21 benthic macro-invertebrate taxa were recovered from mollusks (bivalves & gastropods), ephemeropterans , odonates, dipteran larvae and oligochaetes. Dipterans were the most abundant group with 40% of the total benthic macro-invertebrates. EPTs i.e. the taxa most sensitive to poor water quality such as the trichopterans and plecopterans were missing in the samples. Total mean abundance macro-benthos was 4398 ind. m^{-2} up from 868 ind. m^{-2} of November 2014. Taxa/ species number also increased over the same period. *Chironomus* sp. was the most abundant taxon , contributing about 23.2% of the total benthic macro-benthic community with a peak value (502 ind. m^{-2}) at USC. Other abundant taxa were *Chaoborus* and *Tanypus.* EPTs were represented by *Povilla adusta,* Leptophlebids and *Caenis* sp. and all were found at DSC.

Five fish species, including haplochromines (Nkejje) as a single species group, were recorded. Numerically, Haplochromines (Nkejje) dominated the catch contributing 80.4% of all the fishes caught. By weight, *C. gariepinus* (61.7%) was the most dominant followed by haplochromines (27.7%). Lowest fish species diversity (2 species) was recorded at WIC while highest diversity (3 species) was from DSC. Fish abundance was highest at DSC (54.9%) while the lowest (15.7%) was at WIC. Highest biomass (86.5%) was recorded at DSC and lowest (5.1%) occurred at WIC. Catch rates by numbers and weight were highest (2.2 fish per net and 310.7g per net) at DSC. Overall mean catch rates during the March 2015 survey was 1.3 fish/net/night and 119.7g per net per night. Overall there was no evidence found suggesting impacts of the fish cages upon the fish community in the SON fish farm area.

Observations during Quarter 1 of 2015 on key environmental parameters indicate normal, expected conditions of water quality and within permissible limits recommended by NEMA. However general poor occurrence of non-tolerant macro-benthos (EPTs) at WIC may to suggest incipient impacts of the cage facility at the site.

1.0 BACK GROUND

Source of the Nile (SON) fish farm is located at Bugungu in Napoleon Gulf, northern Lake Victoria. The proprietors of the farm have a collaborative arrangement with NaFIRRI, a lead agency in fisheries research and innovations, to undertake quarterly environment monitoring surveys at the farm. The agreed areas for monitoring are: selected physico-chemical parameters (i.e. temperature, dissolved oxygen, pH, conductivity, secchi depth); total suspended solids (TSS); nutrient status; BOD_5) and biological parameters (i.e. algae, zooplankton, macro-benthos and fish). Water and biological samples as well as field measurements were taken at 3 sites: within the fish cage rows (WIC/experimental), upstream (USC/control) and downstream (DSC) of the fish cages. The key research question was: *Does fish cage operations have impacts on the water quality and aquatic biota in and around the SON cage fish farm?* The environment monitoring surveys were projected to cover a full calendar year (i.e. from January to December). The first surveys were undertaken in 2011 and have continued on an annual basis since then.

The present report presents field observations made for the fourth quarter survey undertaken in November 2014 and provides a scientific interpretation and discussion of the results with reference to possible impacts of the cage facilities to the water environment and the different aquatic biota in and around the fish cage site.

2.0 STUDY AREA

Source of the Nile Fish Farm is located at Bugungu area at the western end of the Napoleon gulf in northern Lake Victoria (Fig. 1). The farm lies a few kilometers south of the source of the River Nile and is presumed to be influenced by the headwaters of the river as it flows downstream to the nearby Owen Falls and Nalubaale Dams. The farm currently comprises 426 of fish cages arranged in rows in a west-to-east formation, anchored by weights and buoyed by large plastic floaters. The water depth at the farm/study site ranges from 3.2 to 8.3m with a mean depth of 4.7m. Over the years of operation of the farm, the number of fish cages has steadily increased and the area under cages has expanded. To date the latter has increased to cover what was originally designated as USC or control site. As a result, the monitoring team has had to re-locate the control site (USC) to a point further upstream away beyond the present coverage of the fish cages.

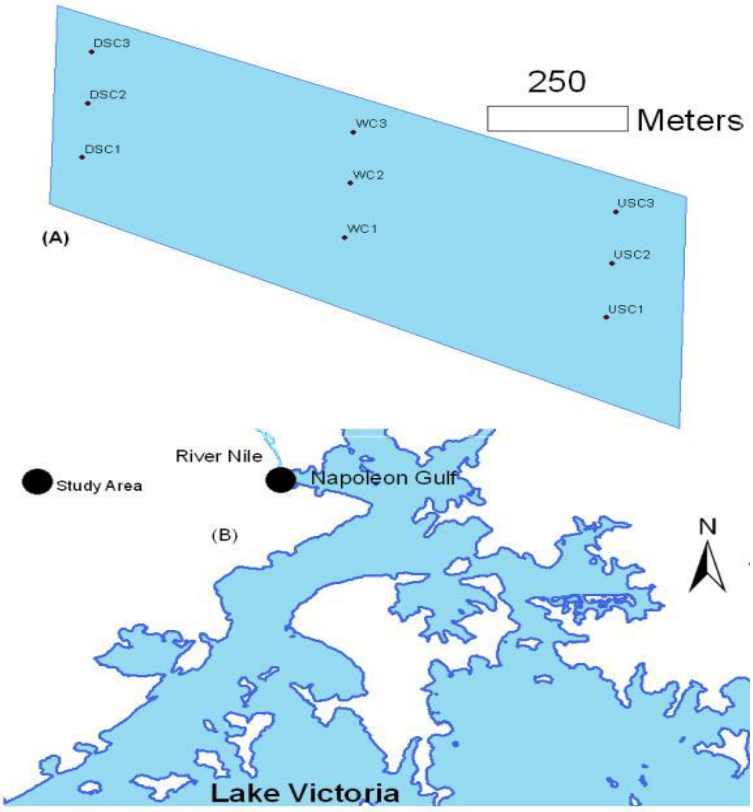

Figure 1. Schematic presentation of the study area (A) and (B), map of the study area showing location of SON Fish Farm and study transects: USC- upstream of cages; WIC- within cages and DSC- downstream of cages, in northern Lake Victoria.

3.0 MATERIALS AND METHODS

3.1 Depth profiles and water transparency and GPS positions

An Echo Sounder was used to determine the total depth at each study site. A black and white Secchi disc harnessed with a 1-metre marked rope was used to measure water column transparency. All in-situ measurements were made in triplicate for the purpose of assessing variation in each parameter at each sampling point. Coordinate locations for each site were determined with a GPS device and used to prepare the site location map (Figure 1).

3.2 Physical-chemical environment

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

3.3 Nutrient status

Water samples for the determination of nutrients and algae status were collected with a Van dorn sampler, placed in clean, labeled plastic bottles for laboratory analysis. Water samples for determination of dissolved nutrients (i.e. Soluble Reactive Phosphorus (SRP), Ammonia-nitrogen (NH_3-N), Nitrate-nitrogen (NO_3-N), Nitrite-nitrogen (NO_2-N) and Total Nitrogen (TN)) were filtered and analyzed by spectrophotometric methods following procedures by Stantoin *et al*. (1977). Other water samples were also analyzed for total suspended solids (TSS). Water

samples for determination of algal composition and biomass were placed in clean, labeled glass scintillation vials and examined using an inverted Microscope following methods of Mosille (1984) and Hotzel & Croome (1998).

3.4 Zooplankton and macro-benthos

Three replicate zooplankton samples were collected with a conical net of 0.25m 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. A series of 2, 2, and 5 sub-samples were taken from a well agitated sample using a calibrated automatic bulb pipette, each placed on a plankton counting chamber and examined under an inverted microscope at x100 magnification. Individual organisms were taxonomically identified using taxonomic manuals by Boxshall & Braide (1991), Korinek (1999), Korovchinsky (1992) and Koste (1978). Members of each species were enumerated.

Generation of macro-benthos data involved taking sediment samples with a Ponar grab (open jaw area, 238cm^2). Three replicate hauls were taken from each sampling point. The bottom type and texture was determined by visual examination and feel between two fingers. Each haul was concentrated placed in clean, labeled sample bottle, and preserved with 5% formalin. Each replicate sample was rinsed with tap water and spread out on a white plastic tray. Benthos were sorted from the sediment using forceps and each sample examined under a dissecting binocular microscope at x 400 magnification. Identification was done using taxonomic manuals by Pennak (1953), Mandhal-barth, (1954) and Epler (1995). All taxa were recorded and individuals of each taxon enumerated.

3.5 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 to 1900hr and retrieved the following day between 0600hr and 0700hr. Fish caught by different nets in each fleet were sorted and identified as in Greenwood (1966). Specimens of haplochromines that are not easily identifiable in the field 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 and Total Length (TL), for fishes with entire fins. Biometric data (Total and Standard length, body weight, sex and gonad maturity state, stomach fullness and fat content) were recorded for individual fishes. Fish stomachs were preserved for laboratory analysis of the contents as in Bagenal and Braun (1978). The fish were further examined for any infection (parasitic or bacterial) both on the surface and within the visceral cavity.

4.0 RESULTS AND INFERENCES

4.1 Physico-chemical parameters

4.1.1 Total depth

Total depth at the cage sites ranged between 2 m (DSC) to 17 m (USC), with the shallowest points being at the sampling site 3 located close to the shorelines (Fig. 2). The deep waters at USC allows for more water to flush downstream through the cages.

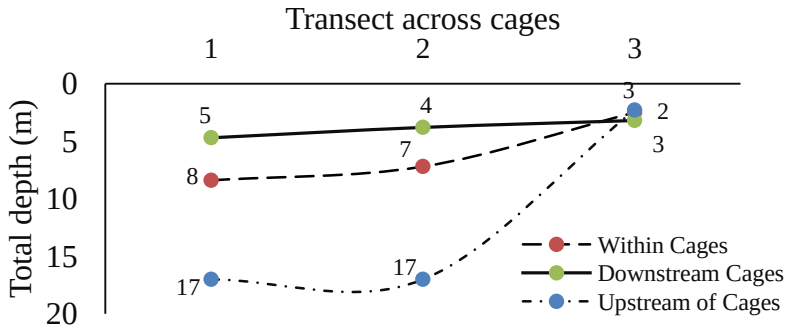

Figure 2. Depth profile across the transects, March 2015

4.1.2 Secchi depth

Secchi depth (which is a measure of light transparency through the water column and an indicator of the presence of floating particles such as algae and other suspended materials) did not vary much through the sampling sites, ranging between 1.2 and 1.3 metres as shown in Table 1. This range was considered suitable for cage fish farming.

Table 1: Secchi depth across the three transects, March 2015

Transect	Mean ± SD
USC	1.2 ± 1.06
WC	1.3 ± 0.00
DSC	1.2 ± 0.06

4.1.3 Turbidity

The observed turbidity ranged between 1.1 and 12.4 NTU (Fig. 3). This however was considered to be low and good for cage fish farming. High turbidity up to 200 NTU can reduce on light visibility and also clog fish gills. It is directly related to the presence of floating algae and other suspended particles. In excess it can interfere with light transparency and the ability of fish to locate its food. There appeared to no influence from the fish cages on this parameter.

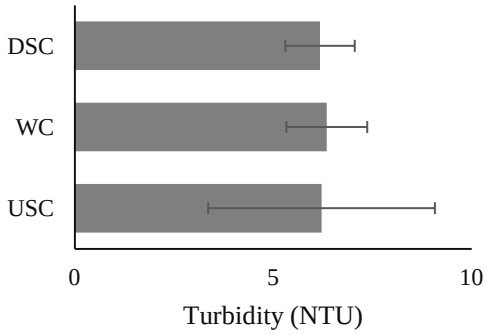

Figure 3. Trend in turbidity across the study transects, March 2015

4.1.4 Dissolved oxygen

Oxygen is an important parameter in cage fish farming. The minimum amount of dissolved oxygen for fish production is 3mg/L (Chapman, 2000; Joseph *et al*, 1993). Observations in the current survey (Fig. 4) showed that dissolved oxygen was higher at USC (mean 7.5 ± 0.5 mg/L) and decreased towards DSC (6.7 ± 0.01 mg/L). This range however is high enough to support the cage fish farming.

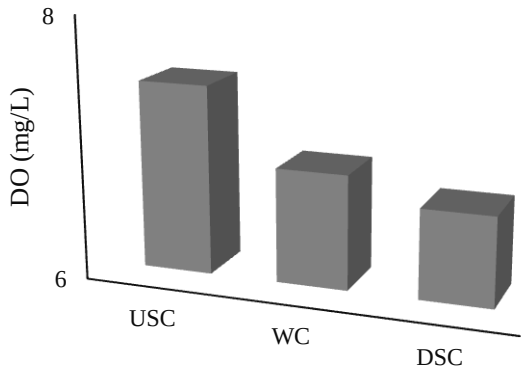

Figure 4. Dissolved oxygen across the cage sites, March 2015

4.1.5 Temperature

Warm temperature is a requirement for cage fish farming. The measured temperature was lower at USC (27.2 ± 0.32 °C) and warmest at WC (27.4 ± 0.25 °C) as shown in Figure 5. The temperature was generally within the optimal range of 25 to 32°C considered suitable for freshwater aquaculture production (Joseph *et al*, 1993). Any shift in temperature above or below the optimal range has an impact on the metabolic rate of the fish.

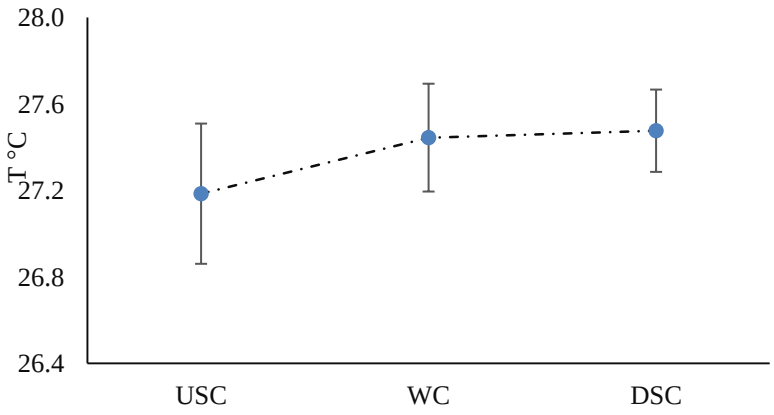

Figure 5. Temperature variation across study sites, March 2015

4.1.6 pH

This parameter was lowest at USC (7.8 ± 0.08) and highest at DSC (8.9 ± 0.0) where it was more alkaline (Fig. 6). The pH variation however was still within the optimal range (6 – 9) for cage fish culture (Chapman, 2000). Low pH below 6 or above 9 is not suitable for fish health as the fish may suffer stress.

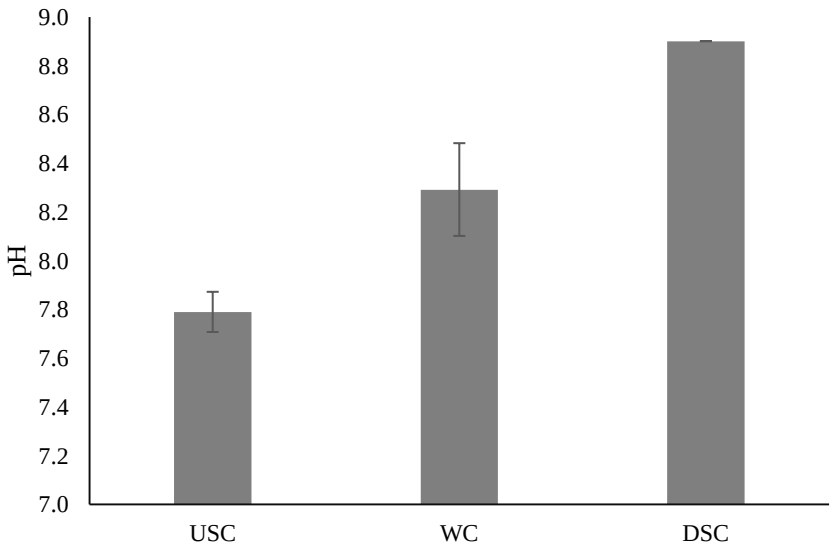

Figure 6. Variation of pH across study sites, March 2015

4.1.7 Conductivity

This parameter indicates the presence of dissolved ions in a water column. Conductivity was higher at WIC (101.3 ± 0.22 μScm^{-1}) than at USC and DSC (Fig. 7) but the difference was not significant. The conductivity variation between 99 to 110.0μScm^{-1} is within the normal range for Lake Victoria and other fresh water bodies of Uganda. Conductivity values below 200 μScm^{-1} are an indication of pristine conditions (Wetzel, 1983).

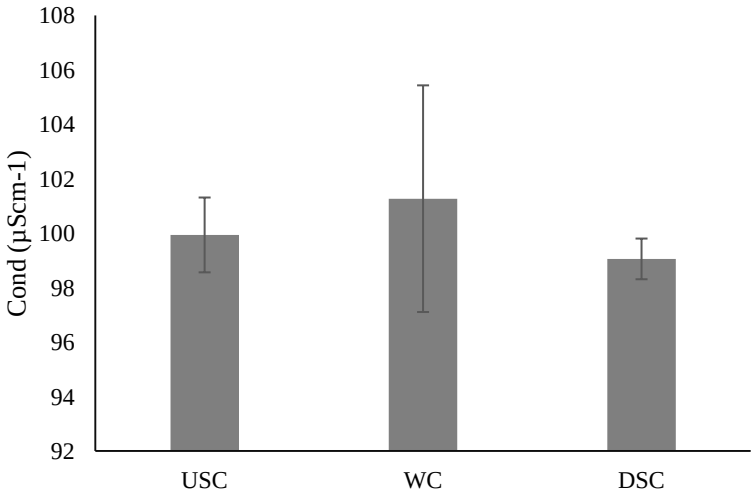

Figure 7. Variation of conductivity across study sites, March 2015

The observations on the various physico-chemical parameters investigated do not indicate major signs of water quality degradation as a result of the fish cages. This situation is probably influenced by the flushing effect of the river as the fish cages are located upstream of the Source of the River Nile.

4.2 Nutrient status

4.2.1 Soluble reactive phosphorus (SRP)

This parameter increased, from 0.018mg/l at USC, 0.022mg/l at WIC and to 0.023mg/l at DSC (Fig.8). The slight increase at WIC and DSC, was probably due to presence of uneaten feed and excretory products of fish in cages (Bureau and Cho 1999) which were carried downstream and the anoxic conditions created cause regeneration of phosphorus from the sediments.

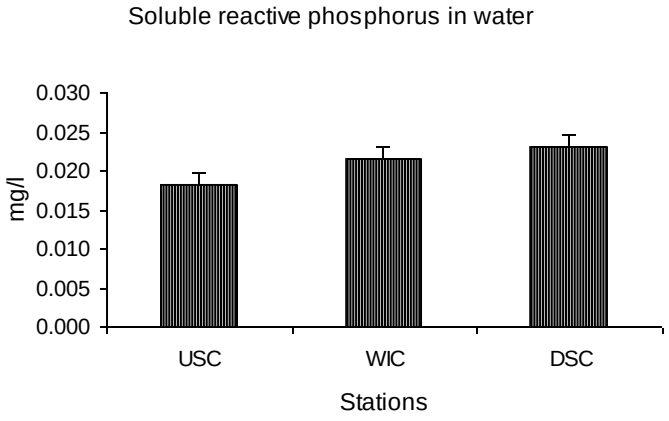

Figure 8. Variation of Soluble reactive phosphorus across study sites, March 2015

4.2.2 Nitrate-Nitrogen

The mean nitrate-nitrogen levels did not vary much in all the sampled sites. The values increased slightly from 0.043mg/l at DSC, to 0.048mg/l at WIC and 0.051mg/l at USC (Fig. 9).

Higher nitrate levels at USC could probably be due to agricultural runoff laden with fertilizers and animal wastes (Hargreaves, 1998, Rabalais 2002). The reduction in NO_3-N levels WIC and DSC could be due to uptake by phytoplankton and by denitrification (Wetzel, 2001). Nitrate is the most oxidized form of nitrogen in nature and is relatively non-toxic to fishes (Zhang & Chen 2004). However when nitrate concentrations become excessive and in presence of other factors, eutrophication and associated algae blooms can become a serious environmental problem.

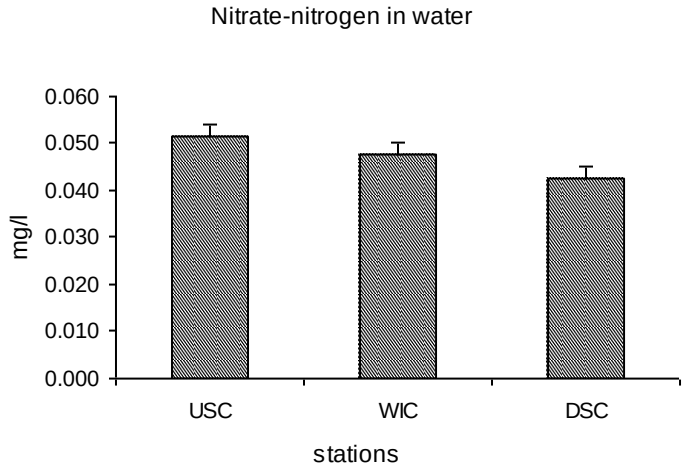

Figure 9. Variation of nitrate-nitrogen at the study sites, March 2015

4.2.3 Ammonium-Nitrogen

Ammonia-nitrogen was generally low at all sampled sites; ranging from 0.009mg/l at DSC, to 0.011mg/l at USC and WIC (Fig. 10). Higher ammonia levels at USC& WIC was probably due to bacterial decomposition of organic material such as dead aquatic plants, plankton and fish farm wastes i.e. fish excretion and uneaten fish feed (Moss,1998).

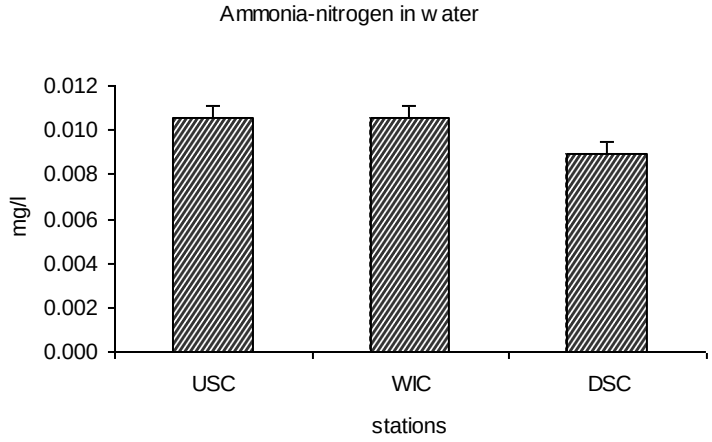

Figure 10. Variation of ammonium-nitrogen at the study sites, March 2015

4.2.4 Total Nitrogen (TN) and Total Phosphorus (TP)

The mean TN values were higher upstream/USC (0.05 mg/l) probably due to activities within the catchment then decreased to 0.022 mg/l at WIC probably due to deposition within the sediment and thereafter increased slightly to 0.039 mg/l at DSC (Fig. 11). Phosphorus concentration increased gradually from USC, through WIC and was highest at the downstream/DSC site (Fig. 12). Low Most of the phosphorus used by aquatic plants and phytoplankton is recycled.

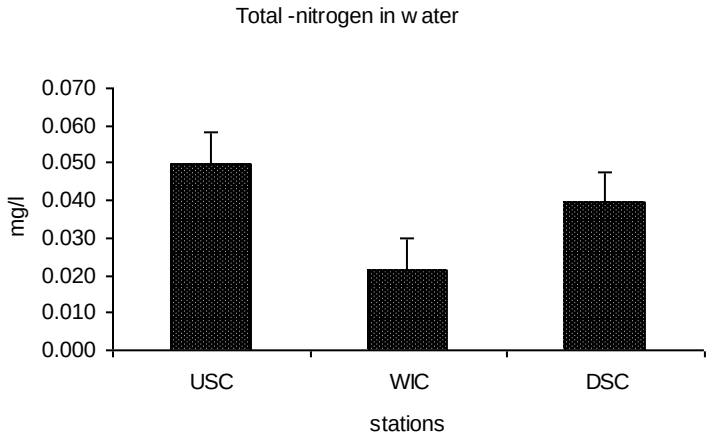

Figure 11. Variation of Total Nitrogen at the study sites, March 2015

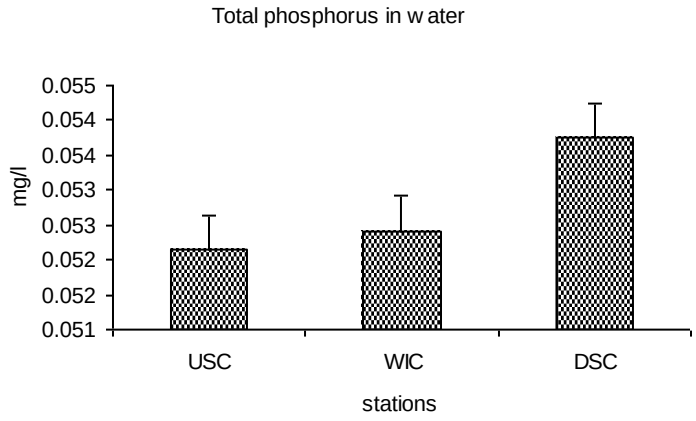

Figure 12. Variation of Total Phosphorus at the study sites, March 2015

4.2.5 Total Suspended Solids (TSS)

Total suspended solids (TSS) decreased gradually from the upstream/USC site (7 mg/l) through the cage fish site/WIC (6 mg/l) site and registered lowest values at the downstream/DSC site (4 mg/l) (Fig. 13). Low TSS values at DSC were probably a result of the flushing effect given the

downstream position of this site. Highest values recorded at USC may be associated with agricultural land use (Walmsely *et al*, 1980). Partial shading by suspended solids can favour the development of cyanobacteria blooms (Harding & Paxton, 2001).

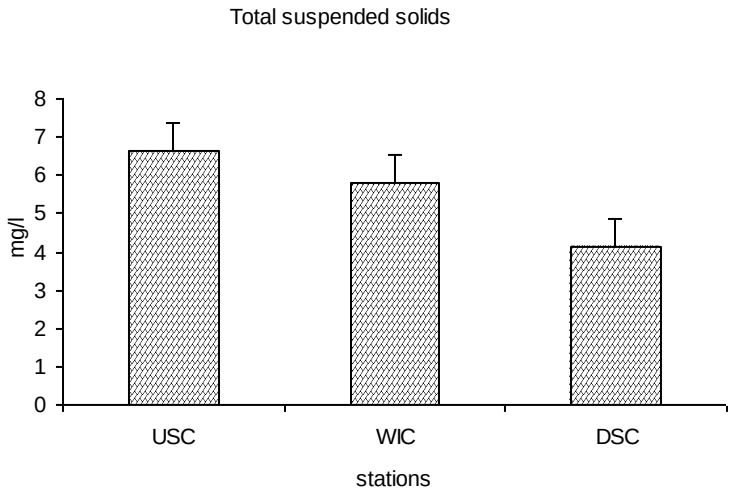

Figure 13. Variation of Total Suspended Solids at the study sites, March 2015

The levels of all measured parameters above were below those considered toxic to fish. However, the recorded phosphate levels were less than the normal range i.e. 0.1mg - 0.2mg/l **(**Sreenivasan, 1965) for the sustenance of phytoplankton density which form natural fish food especially for tilapines. Ammonia levels showed a comparable pattern. In fish culture, ammonia is limited to 0.2 - 2.9 mg/l-ionized ammonia (NH4+ (Joseph *et al,* 1993). The concentration of total suspended solids (TSS) in all sampled sites was generally low (< 25 mg/l) according to Maitland (1990). The observed range is desirable for fish culture as high particulate matter may clog fish gills.

According to Boyd (1996), ammonia level of (0.01- 0.05mg/l) is considered safe while nitrite levels of (1 or 2 mg/l) are harmful to fish and other aquatic organisms**.** The permissible levels by NEMA are for ammonia - nitrogen: 10mg/l; for nitrite-nitrogen: 2 – 20 mg/l; for soluble reactive phosphorus: 5.0 mg/l and for total suspended solids: 100mg/l). Although all investigated nutrients were found to be at low levels, they may occur at high levels in the sediment.

(**N.B.** water analysis is useful in the assessment of river pollution but sediments can also serve as pollution indicators

4.3 Algal community

4.3.1 Composition and biomass

Five major taxonomic groups: Blue-greens, Greens, Diatoms and Cryptophytes were the found in samples from the three study transects (Figure 14) (Table 2). Blue-green algae dominated the biomass with upstream site/USC registering the highest biomass. The downstream transect (DSC) had the highest biomass of green algae. Notably, total algal biomass at all the three

transects was higher than that recorded during the November 2014 survey. The colony-forming algae of the genera *Microcystis, Aphanocapsa, Chroococcus, Anabaena, Chroococuss,*

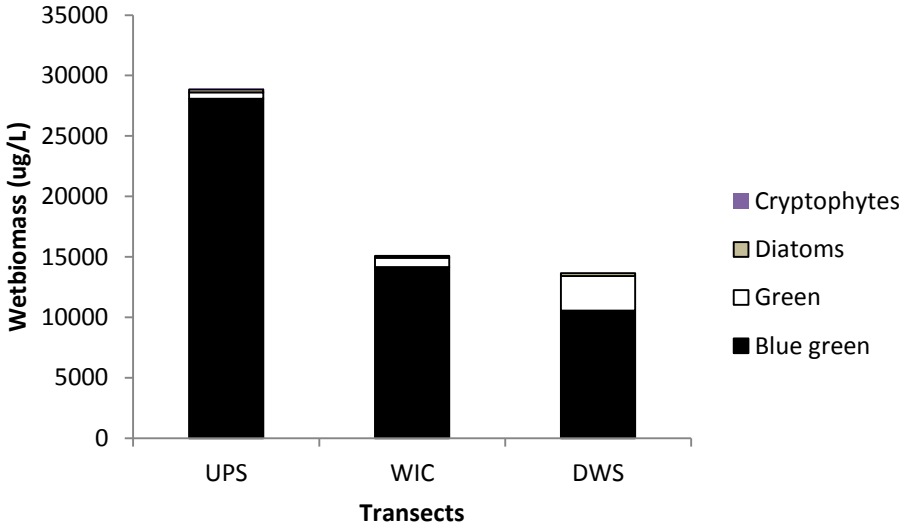

Figure 14. Variation of algal biomass at the study sites, March 2015

Merismopedia, and the filametious alga of the genus *Planktolyngbya,* contributed most to the blue-green algal biomass. Filamentious algae of the genera *Ankistrodesmus, Closterium, Monorophidium,* and the coccoid-forming algae of the genus, *Scenedesmus* contributed the bulk of green algae biomass. *Nitzschia, Navicula, Synedra Cyclostephanodesmsus* were the most prominent algae in the Diatom community, contributing the highest biomass and occurred at all study sites (Table 2).

Table 2. Compostion and occurrence of algal species in the major taxonomic groups across study sites, March 2015

	Transects		
Blue green	**DSC**	**USC**	**WIC**
Aphanocapsa nubilium	X	X	X
Aphanocapsa delicatissima	X	X	X
Chroococcus limnetica	X	X	X
Pseudanabaena spp	X	X	X
Anabaena circinalis	X	X	X
Anabaena compacta		X	
Anabaenopsis tanganyikae	X	X	X
Merismopedia tenussima	X	X	X
Merismopedia glauca	X	X	X
Microcystis spp	X		
Microcystis flos-aquae	X	X	
Microcystis novacekii		X	
Microcystis wasenbergii			X
Aphanocapsa elachista	X		X
Aphanocapsa incerta	X	X	X

Aphanocapsa holistica		X	
Chroococcus aphanocapsoides		X	X
Chroococcus dispersus	X	X	X
Coelomoron pisula		X	
Coelomoron tropicale			X
Coelosphaerium kuetzingianum		X	X
Planktolyngbya tallingii	X	X	X
Aphanocapsa spp		X	X
Planktolyngbya contorta		X	X
Planktolyngbya circumcreta	X	X	X
Planktolyngbya limnetica	X	X	X
Green			
Monoraphidium contortum	X	X	X
Scenedesmus perfolatus	X	X	X
kirchneriella subsolitaria	X	X	X
Ankistrodesmus falactus	X	X	X
Ankistrodesmus setigerus	X	X	
Crucigenia fenestrata		X	
Dicttyosphaerium spp	X		
Ceolastrum microporum	X		
Chlorella spp	X	X	X
Oocystis lucustris	X		
Selenestrum spp			
Stuarastrum cingulum			X
Diatom			
Nitzschia nyassae	X		
Nitzschia acicularis	X	X	X
Nitzschia fonticola	X		X
Navicula gastrum	X	X	X
Synedra cunnigtonii	X		X
Cyclostephanodiscus spp		X	X
Total	**30**	**32**	**31**

Total algal species richness (30 at DSC, 32 at USC and 31 at WIC) was comparable across the three study sites (Table 2).

Comparison of algal biomass during this survey (March 2015) with the previous one (November 2014) indicated an overall increase in algal biomass but accompanied by a decrease in the number of major taxonomic groups. An algal bloom of *Anabaena* observed during the survey is attributed to the overall high biomass as well as the high biomass of blue greens across the three study transects. The trends in both biomass and composition are probably related to seasonal changes under influence the nutrient regime as well as weather/climatic changes rather than effects of fish cages. The location of the cages near the headwaters of the River Nile ensures a sustained flushing effect and therefore mitigates potential impacts from the fish cages. At the time of this (March 2015) survey the lake had just under gone turbulence from strong wind action in the area which may have driven nutrients from the bottom sediments to surface

waters thus making them available for algal growth and culminating into the bloom of *Anabaena*. This observation draws support from evidence in annual cycle of stratification and phytoplankton growth in Lake Victoria (Talling, 1966). Most of the inshore areas of Lake Victoria including the Napoleon gulf tend to be dominated by Blue-green algae, (Mugidde (1992, 1993). There has been consistent dominance of blue-green algae in the study area (see previous SON Environment Monitoring reports) in all previous surveys including the baseline survey and therefore such a phenomenon cannot be attributed to the presence of the fish cages.

4.4 Zooplankton community

4.4.1 Composition and species richness

The community was composed of copepods, cladocerans (Crustacea) and rotifers (wheel animalcules). Total zooplankton species numbers across the three study sites was 31. Copepods species richness ranged between 4 and 7; cladocerans 0 and 5 and rotifers 3 and 12. (Fig 15A). Thus the zooplankton species richness has evidently continued to be driven by copepods and rotifers as previously reported (November 2014 report). In the current survey, total species richness was highest at USC 2 (23 species) and lowest at WIC1 (7 species). This trend has been reported in previous surveys where persistent depressions were observed at the site with fish cages (WIC) and high species richness at USC (Mwebaza-Ndawula et al., 2013).The most frequently encountered copepod species (> 89% occurrence) were: *Tropocyclops tenellus* (100%), *Tropocyclops tenellus* (100%), *Thermodiaptomus galeboides* (100%), *Thermcyclops neglectus* (89%) *and Mesocyclops* sp. *(89%)*. This observation has not deviated much from previous surveys (Table 3). Cladocera species with highest frequency of occurrence (>50%) were *Bosmina longirostris* (56%), *Daphnia lumholtzi* (helmeted) (56%) and *Diaphanosoma excisum* (67%) while the rotifers included *Brachionus angularis* (56%), *Filinia opoliensis* (67%), *Euclanis* sp. (78%), *Syncheata* sp. (78%) *Keratella tropica* (89%), *Trichocerca cylindrica (89%)* and *Lacane bulla* (89%) (Table 1).

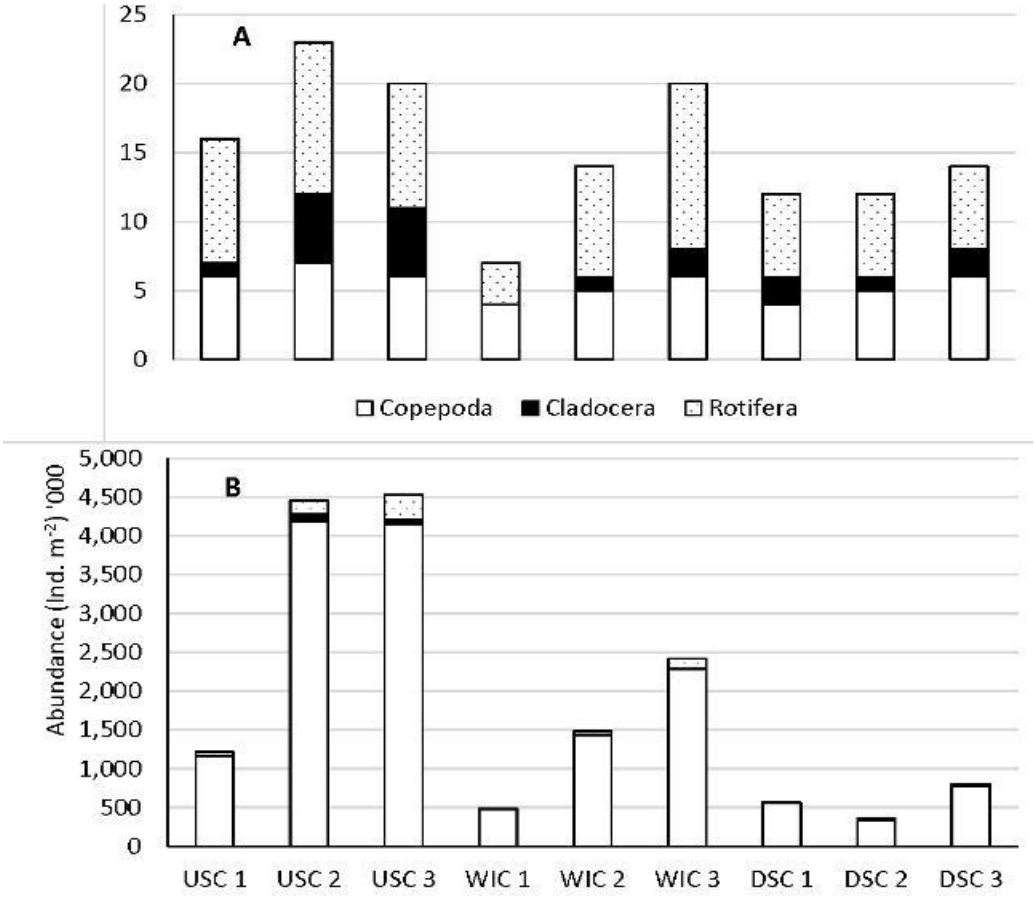

Figure 15. Variation of zooplankton species richness and abundance across study sites, March 2015. **Note** differences in the Y-Axis scales.

Table 3. Zooplankton species composition, distribution and abundance (indiv. m^{-2}) across study sites at SON fish farm, March 2015.

Sites	USC 1	USC 2	USC 3	WIC 1	WIC 2	WIC 3	DSC 1	DSC 2	DSC 3	Minimum	Maximum	%age Occurrence
Depth (m)	2.5	15	14	2	6	7	5	3	5			
Field Time	1130	1120	1130	1240	1230	1200	1240	1300	1340			
Copepoda												
Mesocyclops sp.	1,347	5,053	10,105	2,358	5,053	1,011	-	337	674	-	10,105	89
Thermocyclops emini	3,032	21,473	-	-	-	5,053	-	-	-	-	21,473	33
Thermocyclops incisus	-	10,105	6,063	-	-	-	-	-	674	-	10,105	33
Thermocyclops neglectus	3,368	49,262	45,473	-	4,379	1,011	9,768	2,021	2,695	-	49,262	89
Tropocyclops confinnis	30,315	37,894	89,935	7,747	22,568	13,810	2,695	4,042	50,189	2,695	89,935	100
Tropocyclops tenellus	24,589	74,525	85,893	22,568	36,041	20,547	28,294	5,389	44,125	5,389	85,893	100
Thermodiaptomus galeboides	22,568	39,157	53,557	4,379	11,116	13,810	2,358	13,137	17,179	2,358	53,557	100
Calanoid copepodites	17,852	109,893	143,492	5,389	37,389	49,852	3,032	9,095	16,505	3,032	143,492	100
Cyclopoid copepodite	313,594	804,617	933,709	165,050	446,813	429,129	137,934	141,471	254,648	137,934	933,709	100
Nauplius larvae	745,081	3,032,786	2,786,980	266,437	872,405	1,744,810	370,183	162,692	386,688	162,692	3,032,786	100
Cladocera												
Bosmina longirostris	1,684	12,631	2,021	-	1,684	-	674	-	-	-	12,631	56
Ceriodaphnia cornuta	-	31,578	10,105	-	-	337	-	-	-	-	31,578	33
Chydorus sp.	-	16,421	10,105	-	-	-	-	-	-	-	16,421	22
Diaphanosoma excisum	-	8,842	17,179	-	-	5,389	1,011	1,347	337	-	17,179	67
Moina micrura	-	18,947	16,168	-	-	-	-	-	1,684	-	18,947	33
Daphnia lumholtzi(helmeted)	-	2,526	-	-	1,347	-	337	674	1,011	-	2,526	56
Rotifera												
Ascomorpha sp.	-	1,263	-	-	-	-	-	-	-	-	1,263	11
Brachionus angularis	3,368	-	6,063	-	-	7,410	1,347	1,684	-	-	7,410	56
Brachionus calyciflorus	-	21,473	-	-	1,347	1,347	-	-	-	-	21,473	33
Brachionus dimidiatus	-	-	-	-	-	337	-	-	-	-	337	11
Brachionus falcatus	-	2,526	-	-	-	-	-	-	-	-	2,526	11
Brachionus forficula	-	-	-	-	-	1,011	-	-	-	-	1,011	11
Euclanis sp	337	5,053	2,021	1,684	4,716	2,358	-	-	3,368	-	5,053	78
Filinia longiseta	1,011	-	-	-	-	2,021	-	-	-	-	2,021	22
Filinia opoliensis	6,400	12,631	7,074	-	3,705	2,021	3,032	-	-	-	12,631	67
Keratella cochlearis	-	6,316	1,011	-	-	2,358	-	-	-	-	6,316	33

Keratella tropica	8,421	34,105	47,494	5,389	17,179	26,610	2,021	-	4,379	-	47,494	89
Lecane bulla	24,757	48,631	236,964	7,074	9,431	83,704	-	20,042	11,789	-	236,964	89
Lecane luna	-	-	3,032	-	-	-	-	-	-	-	3,032	11
Polyarthra vulgaris.	1,347	-	-	-	-	-	-	3,368	-	-	3,368	22
Synchaeta pectinata	-	-	-	-	-	-	-	-	3,705	-	3,705	11
Synchaeta sp.	2,358	20,210	9,095	-	6,400	5,726	337	1,347	-	-	20,210	78
Trichocerca cylindrica	7,074	24,000	6,063	-	5,726	337	2,021	2,358	1,684	-	24,000	89

4.4.2 Relative abundance and species richness patterns

Two upstream sites (USC2 and USC3) registered highest total numerical abundance (4,451,917ind. m^{-2}) and USC3 (4,529,600ind. m^{-2}) while lowest abundance occurred at DSC2 (369,004 ind. m^{-2}) and WIC1 (565,042ind. m^{-2}) (Fig. 15B). The two abundance figures are so far the highest upstream since the monitoring of this cage site started (Mwebaza-Ndawula et al., 2013).There was an increasing trend of abundance from DSC sites through WIC to USC (Fig 15B). Copepods were the main contributors of total abundance with range of approximately 92%-98%. Numerical abundance was at all study sites dominated by copepods followed by rotifers while in terms of species richness, rotifers had the greatest contribution followed by copepods (Fig. 16A & B); records that are similar to those of previous surveys.

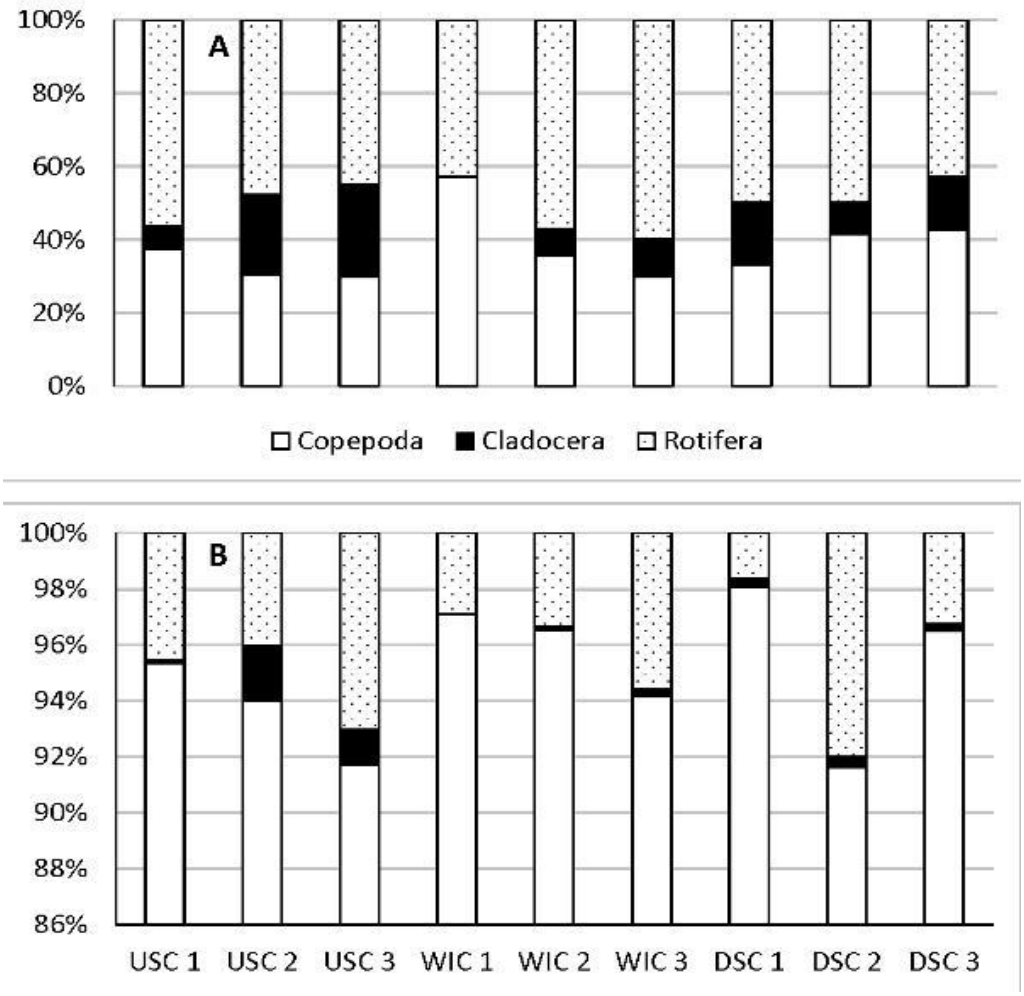

Figure 16. Relative species richness (A) and numerical abundance (B) across study sites, March 2015.

It is not certain if some of the trends recorded in the present survey are true feature that can be attributed to the presence of fish cages. It will therefore require further support and confirmation from subsequent surveys. At present it cannot be concluded if fish cages can still be considered to have impacts especially on zooplankton species diversity as reported in Mwebaza-Ndawula et al. (2013).

4.5 Macro-benthic community

4.5.1 Composition and abundance

The benthic community was constituted by twenty one benthic macroinvertebrate taxa divided among bivalves, gastropods, ephemeropterans ,odonates, diptera and oligochaetes. Like in the previous surveys, Diptera was the most abundant group with 40% of the total bentic macro-invertebrates obtained. Gastropoda was the second abundant (29.3%) followed by Bivalvia (about 19%). Two most sensitive taxa to water quality: Trichoptera and Plecoptera were missing in the samples (Table 3). The total mean abundance the benthos was 4398 ind. m^{-2} up from 868 ind. m^{-2} in ^{the} preceding survey. This increase in the total mean abundance of benthic mcro-invertebrates was a reflection of increases in the abundance of macro-benthos at the study sites i.e. the USC, WIC and DSC, where increased from 299, 187 and 383 ind. m^{-2} to the current 1737, 1947 and 714 ind. m^{-2} respectively. As well, the numbers of taxa/species also increased. The most abundant mollusk species this time was *Melanoides tuberculata* with the highest density of 504 ind. m^{-2} at USC (Table 3). *Chironomus* sp. were the most abundant species among dipterans and of all the macro-benthos, contributing ca. 23.2% of the total benthic macroinvertebrates abundance (Table 1 & 2). The taxon was most abundant (502 ind. m^{-2}) at the upstream/USC. Other abundant types were *Chaoborus* and *Tanypus* (Table 3). The recovered (EPTs) were represented by *Povilla adusta,* Leptophlebids on addition to the *Caenis* sp., all found at DSC. *Caenis* was also found at USC, while *P. adusta* occurred at WIC. All recovered EPTs occurred in rather low densities (14 to 28 ind. m^{-2}) (Table 3). Libellulids (odonates) were found only in USC (14 ind. m^{-2}). Oligochaetes occurred at both WIC and DSC (Table 3).

The recovery of some EPT taxa in some of the study sites is an indication of improved water quality conditions at the study sites, probably a reflection of seasonal influences such as the current heavy rains which may lead to dilution effects in case of harmful materials introduced in the water from the fish cage area.

4.6 Fish Community

4.6.1 Fish Catch composition

A total of 5 fish species, including haplochromines (Nkejje) as a single species group, were recorded in and around the fish cages. Numerically, *Haplochromines* (Nkejje) dominated the catch contributing 80.4% of all the fishes caught, followed by *Clarias gariepinus* (Mudfish) at 7.8%., *Mormyrus kannume (Elephant snout) at 5.9%, Lates niloticus (3.9%), and Oreochromis niloticus (2.0%).* By weight, *C, gariepinus* was the dominant species (61.7%) followed by *haplochromines* (27.7%), *M. kannume* (6.9%), *O. niloticus* (3.0%), and *L. niloticus* (0.8%). Fish catch rates by numbers were highest at DSC and lowest at WIC (Fig. 17A). Fish species richness did not vary much between study sites. The highest diversity (3 species) was recorded from DSC and USC sites and lowest (2 species) was recorded at WIC (Fig. 17B). The highest biomass (Fig. 17C) was recorded Downstream the cages followed by the Upstream site and Within the cages.

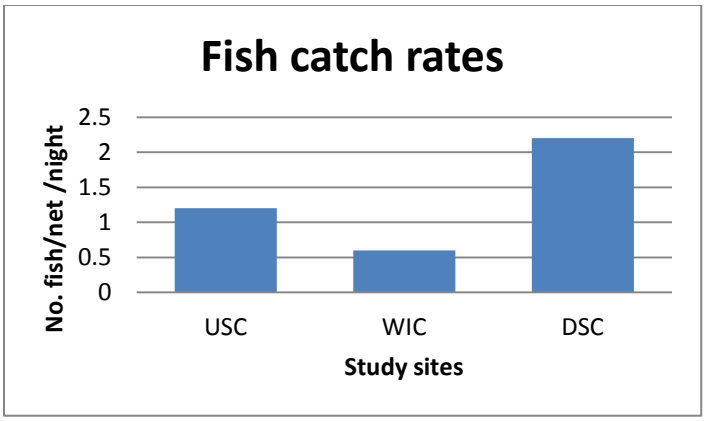

Figure 17A. Fish catch rates (by numbers) at the study sites, March 2015

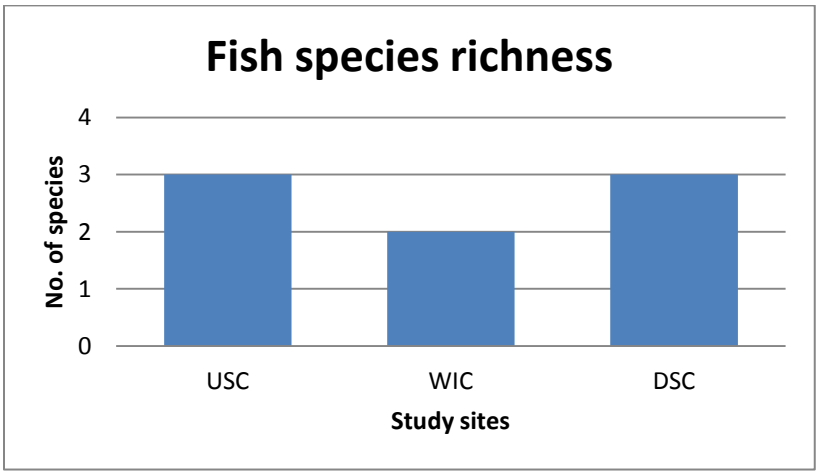

Figure 17B. Fish species richness at the study sites, March 2015

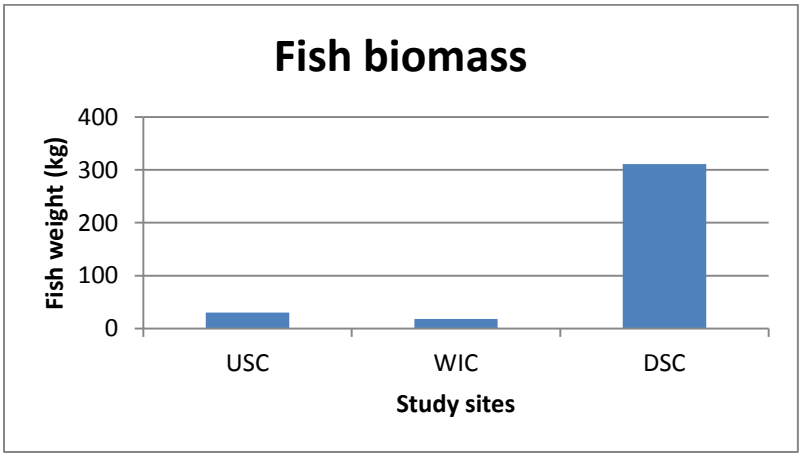

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Figure 17C. Fish biomass at the study sites, March 2015

Haplochromine species diversity

Seven species of haplochromines were recovered during the survey of March 2015 (Table 3). Numerically, *Psammochromis riponianus* (26.8%), were the most dominant followed by *Astatotilapia* "thicklip" and *Mbipia mbipi* (24.4%), *Astatoreochromis alluaudi* (9.8%), Astatotilapia sp. (7.3%), *Paralabodochromis* "blackpara" (4.9%) and *Lithochromis* sp., (2.4%) The highest haplochromine diversity (4 species) was recovered from Downstream the cages followed by Within the cages site (3 species) and the Upstream site (2 species) (Figure 18B). The haplochromines caught belonged to six genera, namely *Astatoreochromis, Psammochromis, Lithochromis, Mbipia, Paralabidochromis, and Astatotilapia.* Haplochromine catch rates by numbers were highest at the site with cages/WIC and lowest at the control site/USC (Fig 18B).

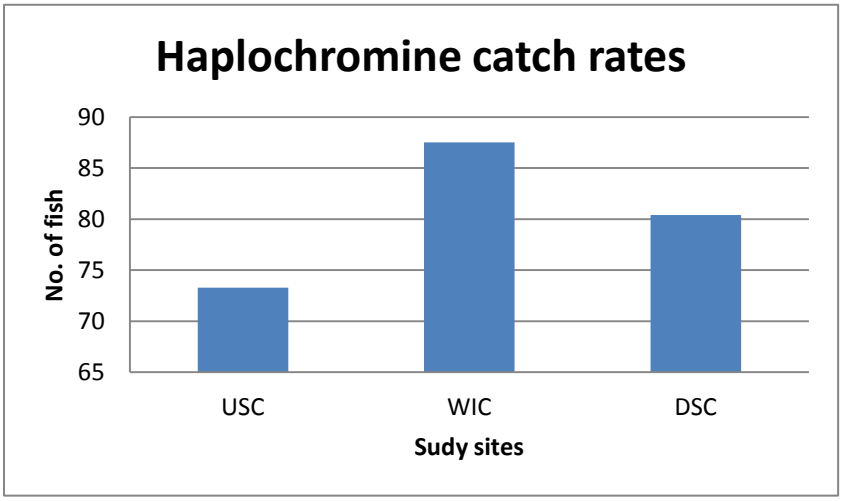

Figure 18A. Haplochromine catch rates (by numbers) at the study sites, March 2015

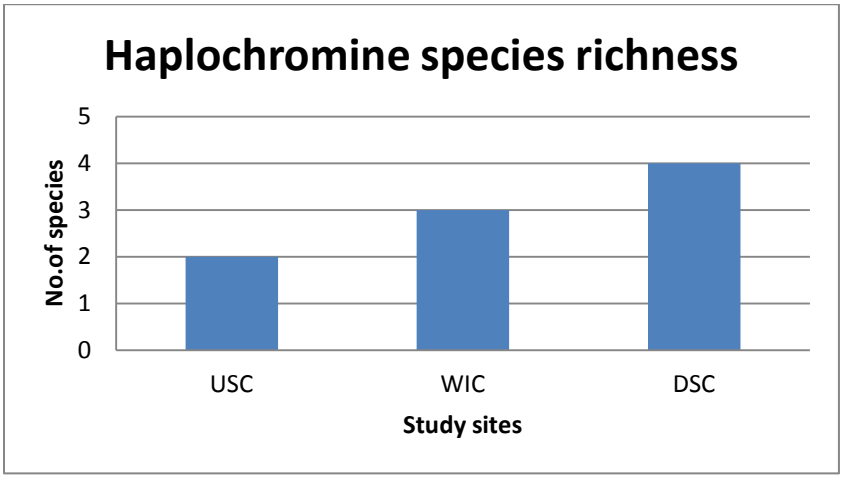

Figure 18B. Haplochromine species richness at the study sites, March 2015

Some aspects of the biology of common fish species

Table 4: Basic biological parameters of fish species caught from SON Fish cage site in, 2013, 2014 and 2015.

Sampling period	**Parameter**	
Date of sampling		March 2015
Season		Dry
Species		
Clarias gariepinus	Size range (cm)	41 - 52.9
	% mature	Mature
	Main food type	Odonata
	Parasites found	0
	Number examined	4
Lates niloticus	Size range (cm)	11.5 – 12.3
	% mature	Nil
	Main food type	Haplochromines
	Parasites found	0
	Number examined	2
Haplochromines	Size range (cm)	7.5 – 15.3
	% mature	Mature
	Main food type	Insect Larvae
	Parasites found (% infection)	0
	No examined	33
Mormyrus kannume	Size range (cm)	18.1 – 24.5
	% mature	Nil
	Main food type	Chironomid larvae
	Parasites found	0
	No examined	3
Oreochromis niloticus	Size range (cm)	19.0
	% mature	Nil
	Main food type	Algae
	Parasites found	0
	No examined	1

Clarias gariepinus and the haplochromines examined during the survey of March 2015 were mature. All the other species examined were immature.

The diet of fishes encountered during the survey of March 2015 comprised mostly fish, mollusks and insects, which are known natural foods of the species caught.

Conclusion

Catch rates by number and weight were lower in March 2015 when compare to that of November 2014. The low catch rate was probably influenced by the prolonged dry season/drought.

All the fish species examined had fed on naturally occurring food organisms, dominated by aquatic insect larvae. Thus cage farming has not yet impacted the wild fish community nor the presence of natural food organisms utilized by the wild fish.

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Appendix 1.

Catch rates (numbers) of fish species from SON FISH cages obtained during 2013, 2014 and 2015

Sampling period			**H1**	**H2**		**H1**	**H2**		
Date of sampling			May 2013	Sep. 2013	Nov 2013	March 2014	Aug. 2014	Nov. 2014	March 2015
Season			Wet	Wet	Dry	Wet	Dry	W	
Family	**Species**	**Site**							
Protopteridae	*Protopterus aethiopicus*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0.08		0	0	0	0	0
		All	0.03	0	0	0	0	0	0
Mormyridae	*Mormyrus kannume*	USC	0.08	0	0	0.3	0	0	0.2
		WIC	0	0.13	0	0	0	0	0.1
		DSC	0		0	0	0.08	0.23	0
		All	0.03	0.04	0	0.1	0.03	0.08	0.1
Characidae	*Brycinus jacksoni*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All	0	0	0	0	0	0	0
	Brycinus sadleri	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0	0	0.3	0	0	0	0
		All	0	0	0.1	0	0	0	0
Clariidae	*Clarias alluaudi*	USC	0	0	0	0	0	0	0

		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All	0	0	0	0	0	0	0
	Clarias gariepinus	USC	0	0.08	0	0.1	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0	0	0	0	0	0	0.3
		All	0	0.05	0	0.03	0	0	0.1
Mochokidae	*Synodontis victoriae*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0.25	0
		All	0	0	0	0	0	0.08	0
	Synodontis afrofischeri	USC	0	0	0	0.3	0	0.4	0
		WIC	0.13	0.5	0	0	0	4.5	0
		DSC	0		0	0	0	6.5	0
		All	0.04	0.17	0	0.1	0	3.8	0
Centropomidae	*Lates niloticus*	USC	0.38	0	0	0.2	0.08	1.5	0.2
		WIC	0.08	0.08	0	0	0.3	0.2	0
		DSC	0.08		0.2	0	0.08	0.4	0
		All	0.18	0.03	0.1	0.03	0.2	0.7	0.1
Cichlidae	*Tilapia zillii*	USC	0	0.125	0.1	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All	0	0.04	0.03	0	0	0	0

	Oreochromis niloticus	USC	0	0	0.1	0	0	0	0
		WIC	0	0	0	0	0.08	0	0
		DSC	0		0	0	0	0	0.1
		All	0	0	0.03	0	0.03	0	0.02
	Haplochromines	USC	0.75	1.5	29.8	8.3	8	0.3	2.8
		WIC	0.25	0.5	46.3	0	0.5	4.5	1.8
		DSC	0		8.3	0	0.5	22.3	5.8
		All	0.33	1.8	28.1	2.7	3	9	3.4
Overall Rates		USC	1.3	0.6	9.3	2.9	2.5	1.8	1.2
		WIC	0.5	0.6	14.2	0	3.4	4.4	0.6
		DSC	0.15		2.8	0.1	0.3	11.7	2.2
		All	0.7	0.8	8.8	1	2.1	6.0	1.3
No of species recovered		USC	3	3	3	3	2	3	3
		WIC	3	4	1	0	3	3	2
		DSC	2		3	1	3	5	3
		All	5	6	5	4	4	6	5

Appendix 2.
Catch rates by weight (g) of fish caught in SON FISH cage site during the 2013, 2014 and 2015 sampling periods

Sampling period			**H1**	**H2**		**H1**	**H2**		
Date of sampling			May 2013	Sep. 2013	Nov.2013	March 2014	August 2014	Nov. 2014	March 2015
Season			Wet	Wet	Dry	Wet	Dry		Dry
Family	Species	Site							
Protopteridae	*Protopterus aethiopicus*	USC	0	0	0	0	0	0	0
		WIT	0	0	0	0	0	0	0
		All	51.3	0	0	0	0	0	0
Mormyridae	*Mormyrus kannume*	USC	47.5	0	0	58.5	0	0	19.7
		WIC	0	42.9	0	0	0	0	4.9
		DSC	0		0	0	24.7	13.5	0
		All	15.8	14.3	0	19.5	8.2	4.5	8.2
Characidae	*Brycinus jacksoni*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All	0	0	0	0	0	0	0
	Brycinus sadleri	USC	0	0	2	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0	0	2	0	0	0	0
		All	0	0	0.7	0	0	0	0
Clariidae	*Clarias alluaudi*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All	0	0	0	0	0	0	0
	Clarias gariepinus	USC	0	228.3	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	235.8	0	0	221.5
		All	0	153.9	0	79.5	0	0	73.8
Mochokidae	*Synodontis afrofischeri*	USC	0	0	0	10.4	0	22	0
		WIC	8.75	22.9	0	0	0	235.6	0
		DSC	0		0	0	0	144.9	0
		All	5.83	7.6	0	3.5	0	134.2	0
	Synodontis victoriae	USC	0	0	0	0	0	0	0

		WIC	0	0	0	0	0	0	0
		DSC	0	0	0	0	0	10	0
		All	0	0	0	0	0	3.3	0
Centropomidae	*Lates niloticus*	USC	189.23	0	0	6.5	5.1	220.3	2.8
		WIC	4.23	0.7	0	0	4.8	171.2	0
		DSC	1.92	0	6.5	0	0.5	22.2	0
		All	65.1	0.2	2.2	18.9	3.5	137.9	0.9
Cichlidae	*Tilapia zillii*	USC	0	9.9	8	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All	0	3.3	2.7	0	0	0	0
	Oreochromis niloticus	USC	0	0	111.7	0	0	0	0
		WIC	0	0.7	0	0	35.8	0	0
		DSC	0		0	0	0	0	10.6
		All	0	0.2	37.2	0	11.9	0	3.5
	Haplochromines	USC	14.5	29.5	481	72.3	75	2.5	24.3
		WIC	5.0	4.5	650..5	0	4	29.5	43.5
		DSC	0		81	0	12.7	375	255.5
		All	19.5	21.9	404.2	24.1	30.6	135.7	107.8
Overall Rates		USC	251.2	243.5	254.6	121.5	28.1	234.6	30
		WIC	18.0	42.5	200.2	0	99.1	325.4	18.3
		DSC	155.8		0.2	235.8	29.1	250.9	310.7
		All	144.6	176.4	165.6	120	52.1	270.3	119.7
No of species recovered		USC	3	3	3	3	2	3	3
		WIC	3	4	1	0	3	3	2
		DSC	2		3	1	3	6	3
		All	5	6	5	4	4	6	5

Appendix 3.
Catch rates (by numbers) of haplochromine species from SON FISH cage site obtained during surveys carried out in the years 2013, 2014.and 2015

Sampling period			H1	H2					
Date of sampling			May 2013	Sep. 2013	Nov. 2013	March 2014	August 2014	Nov. 2014	March 2015
Season			Wet						Dry
Genus	**Species**	**Site**							
Astatoreochromis	*A. alluaudi*	USC	0	0	0.3	0	0	0	0
		WIC	0	0		0	0	0	0
		DSC	0		0.3	0	0	2	1
		All sites	0	0	0.2	0	0	0.7	0.3
Astatotilapia	*A. macrops*	USC	0	0	0	0	0.3	0	0
		WIC	0	0	0	0	0.5	0	0
		DSC	0		0	0	0.3	0	0
		All sites	0	0	0	0	0.3	0	0
	A. martini	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All sites	0	0	0	0	0	0	0
	A. pallida	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All sites	0	0	0	0	0	0	0
	A. "thick lip"	USC	0	0	0.3	0	0	0	2.5
		WIC	0	0	0	0	0	0	0
		DSC	0	0	0	0	0	0	0
		All sites	0	0	0.1	0	0	0	0.8
	A. "pink anal"	USC	0	0	0	0.3	0	0	0
		WIC	0	0	0	0	0	2	0
		DSC	0		0	0	0	0	0
		All sites	0	0	0	0.1	0	0.7	0
	Astatotilapia sp	USC	0	0	22.5	8	7	0	0
		WIC	0	0.3	34	0	0	0.5	0.5
		DSC	0	0.8	6.3	0	0	15.8	0.3
		All sites	0	1	20.9	2.7	2.3	5.4	0.3
Harpagochromis	*H. guiarti*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0

		All sites	0	0	0	0	0	0	0
Lipochromis	*L. parvidens*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All sites	0	0	0	0	0	0	0
Lithochromis	*Lithochromis sp*	USC	0	0	0	0	0	0	0.3
		WIC	0	0	0	0	0	2	0
		DSC	0		0	0	0	3	0
		All sites	0	0	0	0	0	1.7	0.1
Mbipia	*M."blue"*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All sites	0	0	0	0	0	0	0
	M. mbipi	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	2.5
		All sites	0	0	0	0	0	0	0.8
Paralabidochromis	*P. "blackpara"*	USC	0	0	5.5	0	0.25	0	0
		WIC	0	0	9.3	0	0	0	0.5
		DSC	0		1.3	0	0	0	0
		All sites	0	0	5.3	0	0.03	0	0.2
	P. redfin	UPC	0	0	0	0	0	0	0
		WUC	0	0	0	0	0	0	0
		DSC	0	0	0	0	0.25	0	0
		All sites	0	0	0	0	0.03	0	0
	P. victoriae	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All sites	0	0	0	0	0	0	0
Psammochromis	*P. riponianus*	USC	0	1.5	1.3	0	0.5	0.3	0
		WIC	0	0.3	0.8	0	0	0	0.8
		DSC	0		0.5	0	0	1	2
		All sites	0	1.8	0.8	0	0.2	0.4	0.9
Ptyochromis	*P. sauvagei*	USC	0.25	0	0	0	0	0	0
		WIC	0	0	2.3	0	0	0	0
		DSC	0		0	0	0	0.3	0
		All sites	0.1	0.4	0.8	0	0	0.1	0
	P. xenognathus	USC	0.25	1.4	0	0	0	0	0
		WIC	0.25	0	0	0	0	0	0

		DSC	0	0	0	0	0	0	0
		All sites	0.2	0.5	0	0	0	0	0
Pundamilia	*Pundamilia sp*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0	0	0	0	0	0	0
		All sites	0	0	0	0	0	0	0
	P. macrocephala	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All sites	0	0	0	0	0	0	0
Xystichromis	*X. "earthquake"*	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0		0	0	0	0	0
		All sites	0	0	0	0	0	0	0
	X. phytophagus	USC	0	0	0	0	0	0	0
		WIC	0	0	0	0	0	0	0
		DSC	0	0	0	0	0	0	0
		All sites	0	0	0	0	0	0	0
Overall Contribution		USC	33.3	75.0	98.3	86.8	97.0	4.2	73.3
		WIC		25.0	100	0	28.6	31.6	87.5
		DSC			89.2	0	50	58.6	82.1
		All sites		70.9	98.3	84.6	81.8	46.4	80.4
No of species recovered		USC	3	1	5	2	4	1	2
		WIC	1	2	4	0	1	3	3
		DSC	0		4	0	2	6	4
		All sites	3	4	6	2	5	7	6