Environment Monitoring Technical Report for the SON Cage Fish Culture Site at Bugungu, Napoleon Gulf, Northern Lake Victoria, September 2013

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EXECUTIVE SUMMARY

Source of the Nile Fish farm (SON) is located in northern Lake Victoria close to the headwaters of the River Nile. The proprietors of the farm have established a collaborative agreement with the National Fisheries Resources Research Institute (NaFIRRI) to undertake quarterly environment monitoring surveys of the fish cage site at Bugungu in the Napoleon Gulf. This activity is a mandatory requirement of the National Environment Management Authority (NEMA) of Uganda. Therefore NAFIRRI undertakes monitoring surveys once every quarter covering selected physical-chemical parameters including water column depth, water transparency, water column temperature, dissolved oxygen, pH, conductivity and nutrient status; algal, zooplankton, macro-benthos and fish communities. While the first quarter survey of 2013 (January-March) was missed out due to late decision, the second quarter monitoring survey was dully undertaken in May 2013 and a technical report was compiled and submitted to the client. The present report covers the third quarter survey (July-September) undertaken in September 2013. 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 quality and selected aquatic biota.

As in all the previous surveys, SON cage study sites were coded as downstream of cages (DSC), within the cages (WIC) and upstream of the cages (USC). However, due to expansion of the cage area, the monitoring team undertook a relocation of the 'upstream' site (USC) because the previous site was now found to lie within the expanded cage area. Also a second 'within-cages' site (i.e. WIC2 or WICb in this report) was introduced in the expanded cage area for greater and effective representation of this important study area.

Physical-chemical parameters 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 of the sampling points were determined with a GPS device. Water samples for determination of nutrient concentrations and algal community were collected with a Van dorn sampler. Selected dissolved nutrients (SRP, NO_2-N and NH_4-N) and Total Dissolved Solids (TSS) were analyzed by spectrophotometric methods. Zooplankton samples were sampled with a Nansen type plankton net of 0.25m mouth opening and 60µm Nitex mesh. The macro-benthic community was sampled with a Ponar grab of 238cm2 open jaw area. All samples were taken in triplicates at each sampling point. Invertebrate samples (zooplankton and macro-benthos) were microscopically examined for determination of species composition (using appropriate taxonomic manuals), distribution and abundance patterns across the three study sites. Fish community was sampled with fleets of gill-nets of varying mesh sizes, taxonomically identified and species numbers and weight recorded for each study site. Observations were also made on selected aspects of the biology and ecology of the fishes.

Highest Secchi depth/water transparency, turbidity, conductivity and pH values were recorded at DSC (1.93m; 8 FTU; 115-118µS/cm; 25.5-25.580C). Dissolved oxygen ranges (6.8 ± 0.49mg/L to 8.0 ± 0.30mg/L) indicated saturated conditions across study sites. Water temperatures (24.9

± 0.07 - 26.2 ± 0.55°C) were within optimal range for freshwater aquaculture production. These observations indicated minimum influence of the fish cages on the water environment.

Mean soluble reactive phosphorus (SRP) and Nitrite-Nitrogen concentrations varied minimally across the study sites (0.0071-0.0074 mg/l and 0.013-0.016mg/l respectively), confirming previous observations. Ammonium-Nitrogen registered the highest value (0.058mg/l) at DSC while Total Suspended Solids (TSS) attained the highest value (4.08mg/l) at USC.

Blue-green algae were dominant all the sites investigated, with highest biomass (600ug/l) recorded at the sites with cages (WIC). This observation was in agreement with previous records, suggesting influence from the fish cages. Two blue green algae species: *Anabaena, Aphanocapsa* and *Planktolyngbya* and 2 diatoms: *Nitzschia* and *Synedra* contributed most to the algal biomass.

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Total zooplankton species richness indicated higher values (12 species) at the sites with cages (WIC). This observation was in contrast to previous findings which showed a persistent depression of zooplankton species number at the cage site. Copepod (250-300x103 ind.m^{-2}) and cladoceran (4 - 4.5x103 ind. m^{-2}) mean densities were higher at USC and WIC while rotifer densities decreased from USC (7x103 ind. m^{-2}) through WIC to DSC (4x103 ind. m^{-2}). Total zooplankton densities were lowest at DSC (< 50 x103 ind. m^{-2}).

Although there was minimal variation of the number of macro-benthos taxa across the three study sites, most categories attained peak concentrations (Bivalvia 392 ind.m^{-2}; Gastropoda 598 ind.m^{-2}; Diptera 532 ind.m^{-2}; Annelida 257 ind.m^{-2}) at the site with cages (WIC). It is however not clear if these observations can be regarded as impacts from the fish cages yet as consistency of the results has not been established.

Downstream of the cages site (DSC) registered higher average number of non-haplochromine fishes than the site with cages (WIC) and upstream of the cages (USC). WIC registered slightly higher average species number of non-haplochromine fishes and much lower average numbers of the haplochromine species than both USC and DSC. These appear to be impacts from the fish cages at WIC but there is need to test for consistency of the observations.

In conclusion, while some observations including minimum variation of nutrient concentrations across study sites, normal or expected ranges of physical-chemical conditions of the water suggest little or no impacts from the fish cages, others such as the elevated algal biomass, peak concentrations of several macro-benthos taxa, higher average species number for haplochromines at the site with cages (WIC)appear to imply influence of the fish cages on the natural biota, although in most cases, tests for consistency of these results is required.

RESULTS

Physical and chemical factors

Upstream of the cages site (USC) remained the deepest point and at downstream of the cages (DSC) was the shallowest.

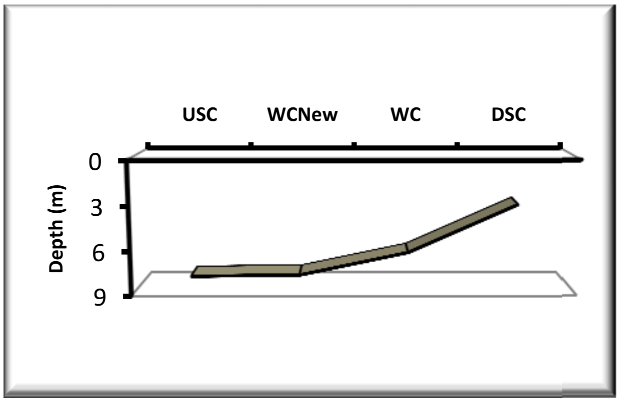

Figure 2. Total depth records at the study sites, September 2013

Secchi depth (SD) ranged between 1.74 ± 0.11 and 1.93 ± 0.12m with highest SD at DSC was high and lowest values at USC.

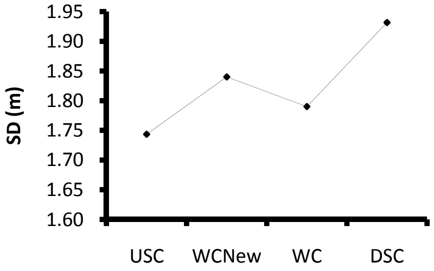

Figure 3. Secchi depth records at the study sites, September 2013

Turbidity ranged between 1.5 and 2.9 FTU with highest turbidity (8 FTU) recorded at DSC.

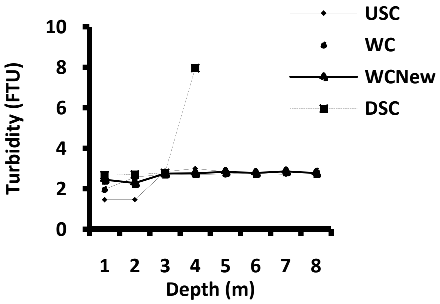

Figure 4. Turbidity at the study sites, September 2013

The turbidity was generally still low compared to that for clear fish ponds which is 25 and muddy ponds being **over NTU** (USEPA, 1986).

Dissolved oxygen ranged between 6.8 ± 0.49mg/L and 8.0 ± 0.30mg/L indicating saturated conditions in the water column. The observed range is notably well above the 3mg/L level suitable for cage fish culture (Chapman, 2000; Joseph, 1993) suggesting favorable oxygen environment for fish and other biota.

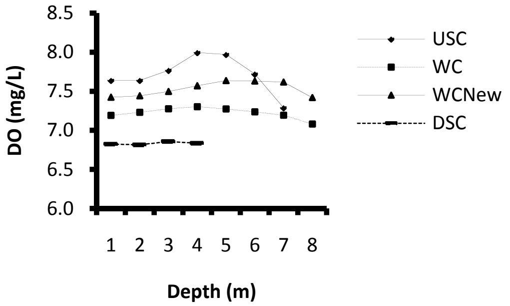

Figure 5. Dissolved oxygen at the study sites, September 2013

Water column temperatures were between 24.9 ± 0.07 and 26.2 ± 0.55°C, being within the optimal range (25 - 32°C) for freshwater aquaculture production (Joseph, 1993). Chapman (2000) recommends a range of 28 to 32°C for optimal growth for hybrid Tilapia. The water was generally cooler towards the bottom (Figure 6). Any shift in temperature above or below the optimal range triggers an increase or decrease in the metabolic rate of the fish. Fish however can detect such variations and will swim to areas where the water temperature is within the optimal range.

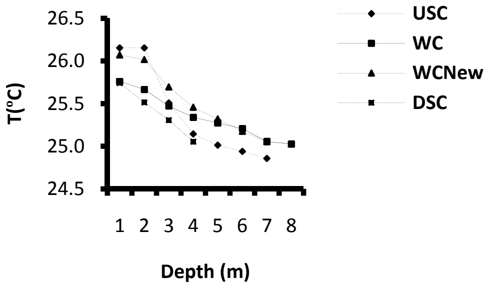

Figure 6. Water column temperature study sites, September 2013

pH ranged between 6.9 ± 0.01 and 7.3 ± 0.57 with minimal variation between surface and bottom waters and slightly higher values at DSC. Tilapia under cage culture does well at a pH range of 6 to 8 (Chapman, 2000). In the event that pH drops below 6 or shoots above 9, this becomes intolerable for most fishes as they begin to suffer stress, which may affect growth.

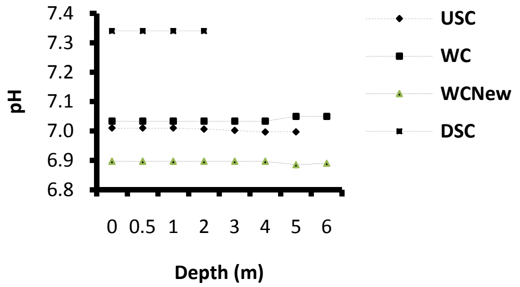

Figure 7. pH records at the study sites, September 2013

Conductivity ranged between 110 ± 0.0 and 118.1 ± 3.68µScm-1, with slightly higher values at DSC. Conductivities between 0 and 200 µScm-1 is an indicator of a pristine or background condition (Wetzel, 1983).

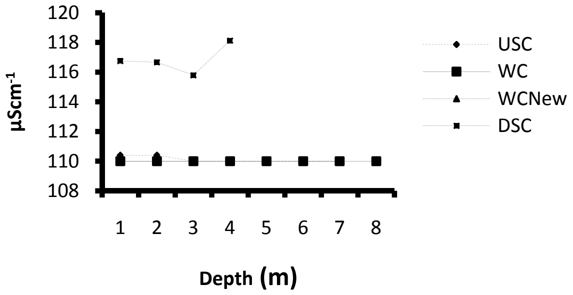

Figure 8. Conductivity at the study sites, September 2013

Nutrient status

Mean soluble reactive phosphorus (SRP) concentrations ranged from 0.0071mg/l (WICb) to 0.0074mg/l (WICa). The difference in SRP levels at WICa and WICb, was probably because the latter cages had been there much longer. The slight increase DSC was probably due to regeneration of phosphorus from bottom sediments (Kisand & Noges, 2003) and the re-suspended phosphorus being released to surface waters by turbulence (Baldwin et al, 2003).

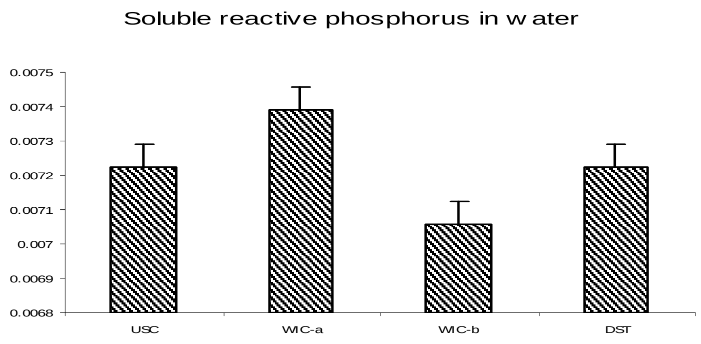

Figure 9. Soluble Reactive Phosphorus at the study sites, September 2013

Nitrite-nitrogen varied from 0.013mg/l at WICa to 0.016 mg/l at DSC (Fig. 10). Particulate and dissolved forms of nitrogen are converted to ammonium by bacterial action and oxidized to form nitrites and eventually nitrates (Hargreaves, 1998). Nitrite is released as an intermediate product during the process of nitrification and denitrification (DWAF 1996c; Bronmark & Hanson, 2005), but is quickly converted to other more stable nitrogen ions (Yves, 1998). High levels are toxic to fish, animals and humans. **How high?**

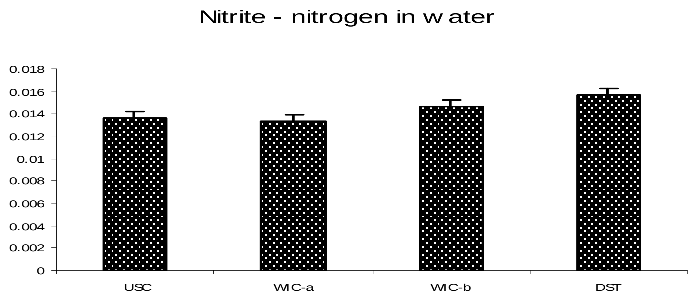

Figure 10. Nitrite-Nitrogen at the study sites, September 2013

Ammonia-nitrogen ranged from 0.0024mg/l (WICa), through 0.012mg/l (WICb) to the highest value (0.058mg/l) at DSC. Ammonia levels were generally low at all the study sites probably under influence of pH, which could have favored conversion to nitrites. The slight increase at DSC may have been due to increase in bacterial action and heterotrophic activity (glucose – mineralization rate) Carr & Goulder (1990). Ammonia accumulation can be toxic and sub- lethal effects can be identified as reduction in growth rates and immune-competence (literature?).

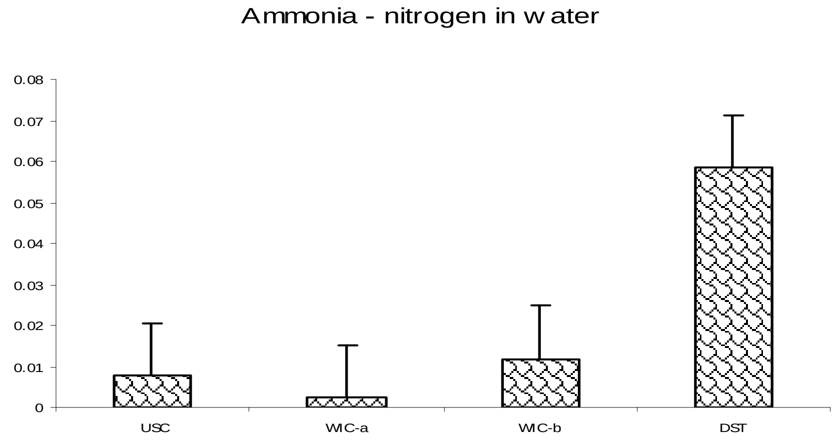

Figure 11. Ammonium-Nitrogen at the study sites, September 2013

Total Suspended Solids (TSS) varied from 2.37mg/l at WICa, 2.38mg/l at WICb, through 3.29 mg/l at DSC to 4.08mg/l at USC. Higher TSS upstream (Fig.12) was probably associated with eroded materials from the catchment (Tlusty *et.al*. 2000).

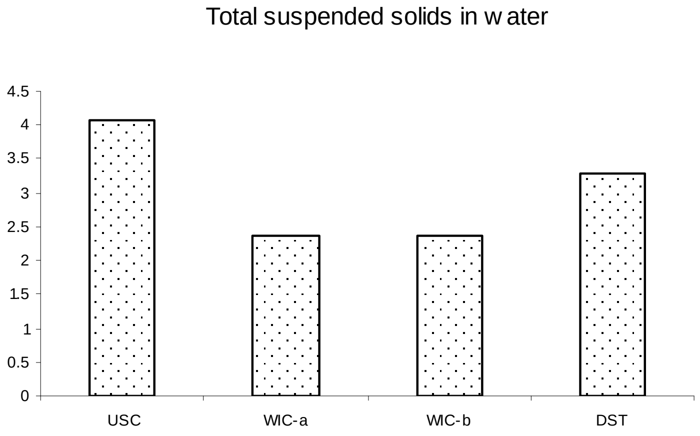

Figure 12. Total Suspended Solids at the study sites, September 2013

Concentrations of the nutrients reported here were all below those considered toxic to fish. Phosphate levels were less than the normal range (0.1mg to 0.2mg/l) (Sreenivasan, 1965) for the sustenance of phytoplankton density which constitutes the natural food tilapia fishes. Ammonia levels showed a similar pattern (ammonia is limited to 0.2 to 2.9mg/l- ionized ammonia (NH4+) for fish culture (Joseph et al., 1993). The concentration of total suspended solids (TSS) in all study sites was low (< 25 mg/l) (Maitland, 1990). The permissible levels by NEMA are: ammonia-nitrogen: 10mg/l; nitrite-nitrogen: 2 – 20mg/l, Soluble Reactive Phosphorus: 5.0mg/l and total suspended solids: 100mg/l as such the levels of the nutrients observed were below the maximum permissible limits.

Algal community

Three taxonomic groups: Blue-green algae, Green algae and Diatoms were encountered each with a number of constituent species (Table 1).

Table .1. Comon algal taxa in the major taxonomic groups at the study sites, September 2013.

Blue-greens	**USC**	**WIC1**	**WIC2**	**DWS**
Planktolyngbya circumcreta	X	x	X	X
Chroococcus limnetica	X	x	X	X
Chroococcus dispersus	X	x		
Aphanocapsa nubilium	X	x		X
Romeria spp	X	x		X
Planktolyngbya limnetica	X	x	X	X
Aphanocapsa incerta	X		X	X
Anabaena circinalis	X	x	x	X
Planktolyngbya tallingii	X	x	X	X
Merismopedia glauca	X	x		
Chroococcus minutus	X			
Psuedonabaena spp	X		X	
Aphanocapsa spp	X	x	X	
Aphanocapsa elachista	X		x	x
Coelomoron pusila		x		
Anabaenopsis tanganikae		x	x	X
Cylindrospermopsis spp		x	x	
Cylindrospermopsis africana				x
Merismopedia tenussima		x	x	x
Coelosphaerium kuetzinganianum		x		
Merismopedia elegans			x	
Cylindrospermopsis cuspis			x	
Aphanocapsa delicatissima			x	
Microcystis spp			x	
Chroococcus aphanocapsiodes				x

Green algae				
Closterium acerosum	x			
Scenedesmus perfolatus	x		x	x
Crucigenia fenestrata	x		x	x
Ankistrodesmus falcatus	x	x	x	X
Closterium acerosum	x			
Monoraphidium contortum	x	x	x	X
Coelastrum costatum	x			
Oosystis gigas		x		
Kirchneriella spp			x	x
Actinastrum hantzschii			x	x
Ankistrodesmus setigerus				x
Pediastrum simplex				x
Diatoms				
Nitzschia acicularis	x	x	X	X
Nitzschia fonticola	x	x		X
Cyclotella spp	x			
Synedra cunnigtonii	x	x	X	x
Nitzschia nyassensis	x	x		
Navicula gastrum		x		
Cyclostephanodiscus spp				
Aulacoseira granulata				x
Total number of species	**26**	**23**	**24**	**25**

Blue-green algae were dominant all the sites investigated, with highest biomass (600ug/l) recorded at the WIC site. Blue green algae of the genera *Anabaena, Aphanocapsa* and *Planktolyngbya* contributed to the highest biomass and were dominant in all samples while *Nitzschia* and *Synedra* dominated the diatom community.

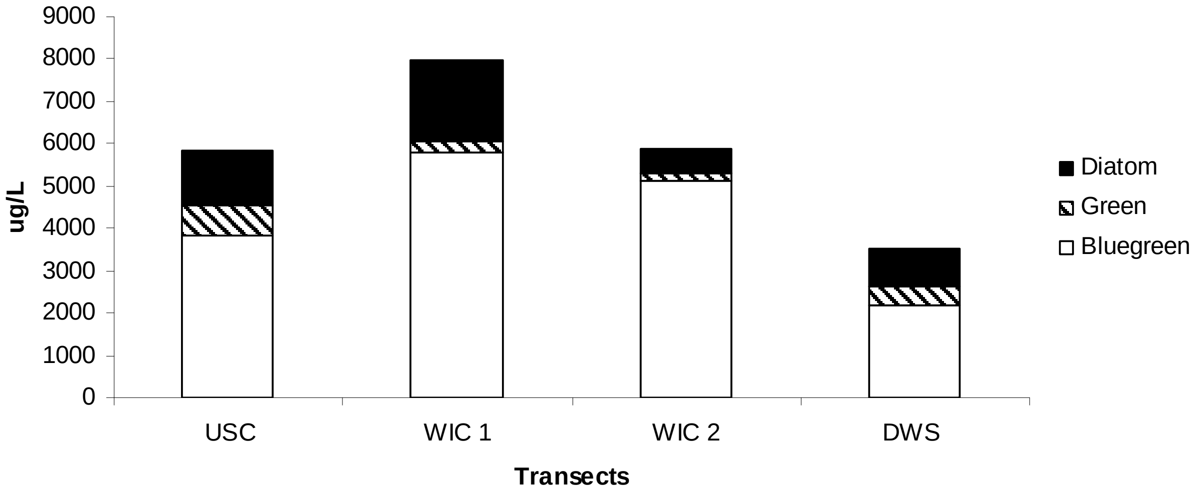

Figure13. Wet biomas of major algal taxonomic groups at the study sites, September 2013.

The consistent high biomass of algae at the site with cages (WIC) may suggest a build-up of nutrients likely from excreta of the fish in cages and uneaten feeds, which upon decomposition could release nutrients to support observed higher algal biomass. Unlike in the June 2012 **13?** survey, where the bloom-forming nitrogen fixing algae: *Anabaena* and *Microsystis* were dominant (suggesting a nitrogen-deficient system), this time around, these species were almost insignificant and this may suggest a build-up of soluble nutrients that may be responsible for the big biomass at the site with cages.

Though reported earlier by Mugidde (1992) changes in the algal composition and biomass may pose a threat to the aquatic biota especially if the toxin producing species dominate the community. Relatively low algal diversity has been recorded in all the three study sites (Table 1) and this is in agreement with observations by (Wetzel 2001) and Knud-Hassen (1997), who noted that phytoplankton diversity is distinctly higher in less productive lakes than in eutrophic lakes like Victoria, and this may be supported by the TSS values observed.

Zooplankton Community

The total zooplankton species number was 28 with copepods (2-7 species) and rotifers (3-7) as the biggest contributers indicating a copepod-rotifer driven community (Table 2). Total species richness indicated relatively high numbers (12) at the sites with cages (WIC) in contrast to previous records showing persistent depression of zooplankton species numbers at this site (Fig. 14)

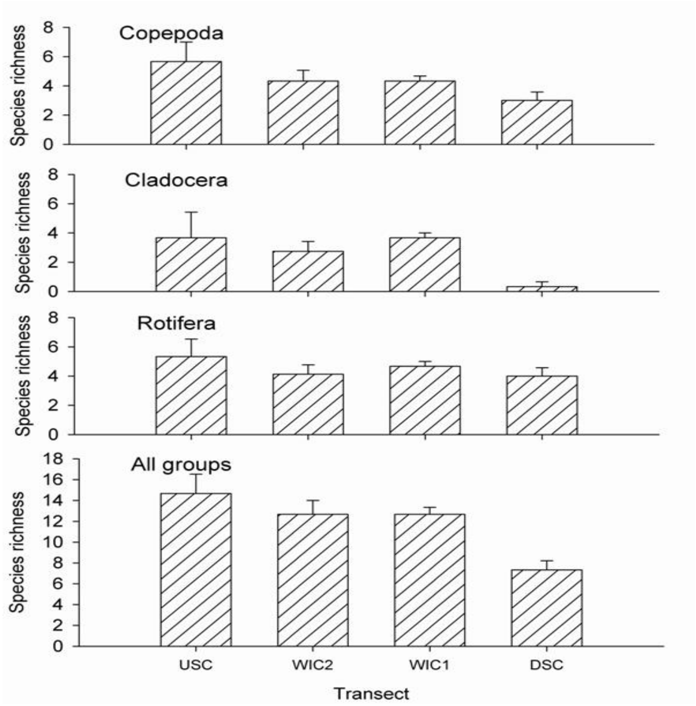

Figure 14. Variation of species richness across study sites, September 2013. *Notice difference in the vertical scales.

The most frequently encountered copepod species (80 - 100% frequency) were: *Tropocyclops tenellus, T. confinnis,* and *Thermodiaptomus galeboides*. Cladoceran species with frequency occurrence above 50% but less than 100% were: *Ceriodaphnia cornuta, Moina micrura* and *Bosmina longirostris* while for rotifers, these were *Euclanis sp, Keratella cochlearis, Trichorceca cyclindrica* and *Lacane luna* (Table 2).

Table 2. Zooplankton species composition, distribution and abundance across study sites at SON, August 2013

Sites	USC1.0	USC2.0	USC3.0	WIC1.0	WIC1.1	WIC2.0	WIC2.1	WIC3.0	WIC3.1	DSC1.0	DSC2.0	DSC3.0	Min	Max	Mean	Occurrence
Copepoda																
Mesocyclops sp.		337	1,011		505		674		2,274					2,274	400	41.7
Thermocyclops emini		1,347	5,389	842		2,695	2,358							5,389	1,053	41.7
Thermocyclops incisus		674	1,011						1,011					1,011	225	25.0
Thermocyclops neglectus		7,579	11,116	1,011	1,179	9,937	5,895	3,200	9,095		808			11,116	4,152	75.0
Thermodiaptomus galeboides	303	3,368	2,189	1,853	3,200		1,347	5,558	4,042		539	404		5,558	1,900	83.3
Tropocyclops confinnis	1,061	5,389	9,095	2,863	11,452	6,231	10,610	7,579	4,800	4,547	943	3,638	943	11,452	5,684	100.0
Tropocyclops tenellus	4,396	14,652	19,031	12,968	18,021	9,937	13,979	14,821	17,684	5,684	2,560	3,503	2,560	19,031	11,436	100.0
Calanoid copepodites	909	1,516	7,747	2,189	3,368	6,231	5,221	14,316	3,032					14,316	3,711	75.0
Cyclopoidcopepodite	32,437	110,819	101,388	96,672	135,576	95,493	128,503	137,934	137,934	17,052	3,638	4,446	3,638	137,934	83,491	100.0
Nauplius larvae	19,856	66,020	60,125	111,998	110,819	89,598	106,103	80,167	118,482	9,777	4,716	3,234	3,234	118,482	65,075	100.0
Species richness	**3**	**7**	**7**	**5**	**5**	**4**	**6**	**4**	**6**	**2**	**4**	**3**	**2**	**7**	**5**	
Cladocera																-
Bosmina longirostris		2,358	2,021	842		842	674	4,716	1,263					4,716	1,060	58.3
Ceriodaphnia cornuta		505	1,179	337		1,516	674	1,011	2,526					2,526	646	58.3
Chydorus sp.			337											337	28	8.3
Diaphanosoma excisum			1,516			2,358	1,011				674			2,358	463	33.3
Daphnia lumhortzi			168	168										168	28	16.7
Dadhnia lumhortzi(helm)			168											168	14	8.3
Moina micrura	1,061	842	1,011	337		674	505	1,853	3,032					3,032	776	66.7
Species richness	**1**	**3**	**7**	**4**	-	**4**	**4**	**3**	**3**	-	**1**	-	-	**7**	**3**	100.0
Rotifera																
Ascomorpha sp.							168							168	14	8.3
Asplanchna sp.					337			1,179						1,179	126	16.7
Brachionus angularis									758					758	63	8.3
B. falcatus				337										337	28	8.3
B. forficula				337										337	28	8.3
Euclanis sp.	2,728	2,695		842	3,537	505				1,592	943	1,617		3,537	1,205	66.7
Filinia opoliensis	152													152	13	8.3
Keratella cochlearis	3,183		1,179	505	505		674		1,516		404			3,183	664	58.3
K. tropica						1,179		842		909				1,179	244	25.0
Lacane bulla	758	1,684					842				808			1,684	341	33.3
L. luna	1,364	674	2,021		3,032			2,695	1,768	682	404	1,347		3,032	1,166	75.0
Polyarthra vulgaris	455	842						1,011	1,768			1,886		1,886	497	41.7
Synchaeta sp.		168				842				682				842	141	25.0
Trichocerca cylindrica	152	1,179	1,853	674	1,347	2,358	2,695	1,179	4,042	1,137				4,042	1,385	83.3
Species richness	**7**	**6**	**3**	**5**	**5**	**4**	**4**	**5**	**5**	**5**	**4**	**3**	**3**	**7**	**5**	
Total species(28)	**11**	**16**	**17**	**14**	**10**	**12**	**14**	**12**	**14**	**7**	**9**	**6**	**6**	**17**	**12**	

Copepod and cladoceran mean densities increased from USC to WIC and decreased at DSC while rotifer densities showed decreasing pattern from USC through WIC to DSC. Total zooplankton densities were lowest (26,192 ± 8004 Ind. m^{-2}) at DSC compared to higher estimates at WIC2 (296,612 ± 9,734) and WIC1 (247,743 ± 15,210 ind. m^{-2}).

Previously reported dominant zooplankton species such as *Thermocyclops neglectus, Tropocyclops confinnis* and *T. tenellus* were still the key species in this survey (Table 1). Rare copepod species such as *Thermocyclops incises, Mesocyclops* sp.; most cladoceran species, coupled with increasing prominence of small-bodied copepods (i.e. *Thermocyclops confinnis and Tropocyclops tenellus*) may be related more to selective predation pressure (Brooks and Dodson, 1965) rather than impacts from the cage operations since they characterize the Lake Victoria zooplankton community structure with or without the fish cages (MwebazaNdawula, 1998).

Macro-benthic community

The macro-benthos community was composed of Bivalvia and Gastropoda (Molluscs); Ephemeroptera, Trichoptera, Plecoptera, Odonata and Diptera (Insecta); Decapoda (Shrimps) and Annelida (Water worms). Representatives of these groups (i.e. *Bysanodonta parasitica, Corbicula africana, Bellamya unicolor, Bulinus sp., Gabbia humerosa, Melanoides tuberculata* (Mollusca); *Caenis* sp., *Povilla adusta*, Psychomiids, *Chironomus* sp., *Chaoborus* sp., *Cryptochironomus*, *Tanytarsus* sp. (Insecta) were recovered at all three study sites (Table 3).

Table 3. Macro-benthos taxa recovered at the study sites, September 2013

Taxa	**Study sites**		
	USC	WIC 1&2	DSC
Bivalvia			
Byssanodonta parasitica	P	P	P
Caelatura monceti		P	
Caelatura hauttecoeuri	P	P	
Corbicula africana	P	P	P
.Mutera bourgguignati		P	
Aspatheria sp.	P	P	
Gastropoda			
Bellamya unicolor	P	P	P
Bulinus sp.	P	P	P
Gabbia humerosa	P	P	
Melanoides tuberculata	P	P	P
Ephemeroptera			
Caenis sp.	P	P	P
Povilla adusta	P	P	P

Leptophlebids	P		
Trichoptera			
Leptocerids		P	
Psychomyiids	P	P	P
Odonata			
Libellulids		P	
Diptera			
Chironomus sp.	P	P	P
Clinotanypus sp.		P	
Cryptochironomus sp.	P	P	P
Tanypus sp		P	P
Tanytarsus sp.	P	P	P
Ceratopogonids		P	P
Chaoborus sp.	P	P	P
Decapoda			
Caridina nilotica		P	
Annelida			
Hirudines	P	P	
Oligochaetes	P	P	
Number of taxa	**18**	**25**	**14**

Bivalvia, Gastropoda, Trichoptera, Diptera and Annelida attained highest number of taxa at WIC (Fig. 15).

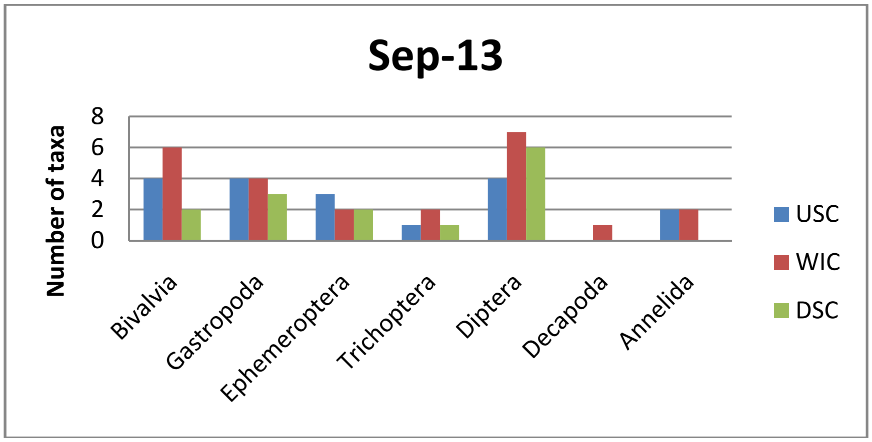

Figure 15. Variation of numbers of macro-benthos taxa across study sites, September 2013

The total number of taxa varied minimally across the study sites (20-22). All categories of macro-benthos except Ephemeroptera and Trichoptera attained peak densities at the site with cages (WIC) i.e. Bivalvia 392 ind. m^{-2}, Gastropoda 588 ind. m^{-2}, Diptera 532 ind. m^{-2}, Annelida 257 ind. m^{-2} while DSC registered the lowest concentration of the different taxa (Fig. 16).

The highest numerical abundance of Ephemeropterans (*P. adusta*, 159 ind. m^{-2}) was recorded at USC. It was also striking to recover highly pollution-sensitive taxa such as Ephemeropterans (28 ind. m^{-2}) and Trichopterans (Psychomyiids, 28,159 ind. m^{-2}) at WIC, i.e. the site with cages (Table 3), which was in contrast to previous observations.

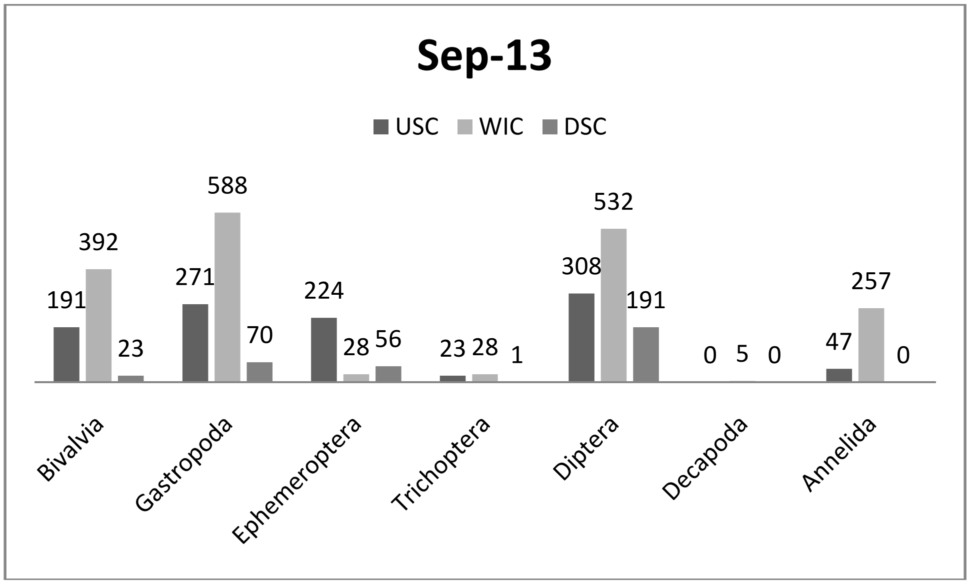

Figure 16. Variation of macro-benthos taxa densities across study sites, September 2013

Fish community

A total of 6 fish species, including haplochromines (Nkejje) as a single species group, were recorded in the vicinity of the cages (Table 4) during the monitoring survey of September 2013. By numbers, Haplochromines (Nkejje) dominated the catch contributing 71.0% of all the fishes caught and was followed by *Synodontis afrofischeri* (Nkolongo) at 12.9%., and *Clarias gariepinus* (Male) at 6.5%. Other fishes caught in small numbers were *Tilapia zillii*, *Lates niloticus* and *Morymrus kannume* (Elephant snout fish), each contributing 3.2%. By weight, *C. gariepinus* (87.2%) was the dominant species followed by *M. kannume* (5.0%), Haplochromines (3.8%), *S. afrofischeri* (2.7%) *T. zillii* (1.1%) and *L. niloticus*. The lowest fish species diversity (2 species) was recorded from the new (WIC 2) site (Windy Bay) while the highest diversity (4 species) was recorded at the old site with cages (WIC1). Three species were recorded from upstream site (USC). Fish abundance was highest in the new (WIC 2) cage site (48.4%) and lowest abundance occurred at the control/upstream site (USC), at the site with cages (WIC 1) and downstream (DSC) of cages (25.8%).

Table 4. Catch rates (numbers) of fish species caught in the study sites, September 2013

Date of sampling			**Sep. 2013**
Season			**Wet**
Family	**Species**	**Study Sites**	
Mormyridae	*Mormyrus kannume*	USC	0
		WIC	0.13
		DSC	
		NS	0
		All	0.04
Clariidae	*Clarias gariepinus*	USC	0.08
		WIC	
		DSC	
		NS	0.08
		All	0.05
Mockokidae	*Synodontis afrofischeri*	USC	0
		WIC	0.5
		DSC	
		NS	0
		All	0.17
Centropomidae	*Lates niloticus*	USC	0
		WIC	0.08
		DSC	
		NS	0
		All	0.03
Cichlidae	*Tilapia zillii*	USC	0.125
		WIC	0
		DSC	
		NS	0
		All	0.04
Cichlidae	Haplochromines	USC	1.5
		WIC	0.5

		DSC	
		NS	3.5
		All	1.8
Overall Rates		USC	0.6
		WIC	0.6
		DSC	
		NS	1.2
		All	0.8
No of species recovered		USC	3
		WIC	4
		DSC	
		NS	2
		All	6

WIC 2 (NS) had the highest average catch rates of fish (1.2) per night compared to WIC 1 and USC each with 0.6 per night (Table 4). On the other hand, WIC registered lower average biomass of fish (42.5 gm night^{-1}) than USC (243.5gm night^{-1} and DSC 243.1g night^{-1}). WIC 1 also registered higher average number of fish species (4) compared to 3 and 2 at USC and WIC 2. (Table 5).

Table 5. Catch rates (numbers) of fish species caught in the study sites, September 2013

Date of sampling			Sep. 2013
Season			Wet
Family	**Species**	**Site**	
Mormyridae	*Mormyrus kannume*	USC	0
		WIC	42.9
		DSC	
		NS	0
		All	14.3
Clariidae	*Clarias gariepinus*	USC	228.3
		WIC	0
		DSC	
		NS	233.3
		All	153.9

Mochokidae	*Synodontis afrofischeri*	USC	0
		WIC	22.9
		DSC	
		NS	0
		All	7.6
Centropomidae	*Lates niloticus*	USC	0
		WIC	0.7
		DSC	
		NS	0
		All	0.2
Cichlidae	*Tilapia zillii*	USC	9.9
		WIC	0
		DSC	
		NS	0
		All	3.3
	Haplochromines	USC	29.5
		WIC	4.5
		DSC	
		NS	31.8
		All	21.9
Overall Rates		USC	243.5
		WIC	42.5
		DSC	
		NS	243.1
		All	176.4
No of species recovered		USC	3
		WIC	4
		DSC	
		NS	2
		All	6

WIC registered much lower numbers (25) of haplochromines than USC (75) and DSC (93.3) (Table 6). However, the distribution of haplochromine species across the three study sites indicated an increasing trend from USC (1 species) through WIC (2 species) to DSC (3 species).

Table 6. Catch rates (numbers) of haplochromine fish species caught in the study sites, September 2013

Date of sampling			Sep. 2013
Season			wet
Genus	**Fish Species**	**Study Sites**	
Astatoreochromis	*A. alluaudi*	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
Astatotilapia	*A. macrops*	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
	A. martini	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
	A. pallida	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
	A. "thick lip"	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
	A. "pink anal"	USC	0
		WIC	0
		DSC	

		NS	0
		All sites	0
	Astatotilapia sp	USC	0
		WIC	0.3
		DSC	0.8
		All sites	1
Harpagochromis	*H. guiarti*	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
Lipochromis	*L. parvidens*	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
Lithochromis	*Lithochromis sp*	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
Mbipia	*M."blue"*	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
	M. mbipi	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
Paralabidochromis	*P. "blackpara"*	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
	P. victoriae	USC	0
		WIC	0

		DSC	
		NS	0
		All sites	0
Psammochromis	*P. riponianus*	USC	1.5
		WIC	0.3
		DSC	
		NS	0
		All sites	1.8
Ptyochromis	*P. sauvagei*	USC	0
		WIC	0
		DSC	
		NS	1.3
		All sites	0.4
	P. xenognathus	USC	
		WIC	
		DSC	
		NS	1.5
		All sites	0.5
Pundamilia	*Pundamilia sp*	USC	0
		WIC	0
		DSC	
	NS		0
		All sites	0
	P. macrocephala	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
Xystichromis	*X. "earthquake"*	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0
	X. phytophagus	USC	0
		WIC	0
		DSC	
		NS	0
		All sites	0

Overall Contribution		USC	75
		WIC	25
		DSC	
		NS	93.3
		All sites	70.9
No of species recovered		USC	1
		WIC	2
		DSC	
		NS	3
		All sites	4

Other than the haplochromines, the rest of the fish species caught in the experimental gillnets were in low numbers.

Fish catch rates were higher in September 2013(176.4g/net/night) than the mean rates calculated for the May 2013 survey (144.6g/net/night). However, the increase was largely due to two big *C. gariepinus* caught at the New (upstream) site (Windy Bay). Although in the past, the downstream station (DSC) has had more fish, in September 2013, there was a shift to the within the cages (WIC) site.
None of the fishes examined during the September 2013 survey had ingested the artificial feeds supplied to the farmed fish.

CONCLUSIONS

1. WIC registered slightly higher average number of non-haplochromine fishes caught and much lower average numbers of haplochromine species than both USC and DSC. These appear to be some impacts from the fish cages at WIC but there is need to test the consistency of these observations.
2. The observed attainment of peak numerical abundance of most categories of macro-benthos and taxa numbers at WIC may be viewed as impacts of the fish cages to the macro-benthos community; however there is need to test consistency of these results.
3. Comparisons of total zooplankton species richness at the study sites showing higher numbers at WIC than previously recorded is a shift from previous records showing persistent depression of zooplankton species at this site.
4. Dominance of blue-green algal biomass at WIC was in agreement with previous records, suggesting an impact from the fish cages.

5. Minimal variation of mean soluble reactive phosphorus (SRP) and Nitrite-Nitrogen concentrations across the study sites is in agreement with previous findings.
6. Ranges of the various physical-chemical parameters observed at the three study sites were mostly normal for freshwater systems and this suggested minimum influence of the fish cages on the water environment.

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