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Technical Report on the Environmental Monitoring of the Cage Area at the Source of the Nile (SON) Fish Farm for Quarter 4: October-December 2011

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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 for technical assistance of NaFIRRI to undertake regular environment monitoring of the cage site as is mandatory under the NEMA conditions. NAFIRRI agreed to undertake quarterly environment surveys in the cage area covering 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 was undertaken in February 2011; the second in May 2011, the third in September 2011 and the fourth quarter survey which is the subject of this report was undertaken in November 2011. 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.

Soluble reactive phosphorus (SRP) was higher at DSC/ downstream (0.0147mg/l) compared to USC/upstream (0.01mg/l) probably through its release from bottom sediments although this trend does not appear to be significant. Nitrite nitrogen varied within narrow limits (0.04-0.043 mg/l) but was significantly higher and comparable at USC and DSC in relation to WIC. Ammonium-nitrogen also varied within narrow limits but was highest at DSC (0.066mg/l) and lowest at WIC (0.058mg/l). Total suspended solids were lower at WIC (0.2 mg/l) and DSC (0.4 mg/l) compared to USC (1.2 mg/l).

Within cages (WIC) site had the lowest zooplankton species number (19) compared to (DSC) (25) and (USC) (25), with rotifers having the highest number of species in all survey sites: (WC (9), DSC (13) and USC (10). Copepods were widely distributed in all sites compared to Rotifera and Cladocera; with *Tropocyclops tenellus, Tropocyclops confinnis, Thermocyclops neglectus* and *Thermodiaptomus galeboides* as the dominant

species. Fourth quarter (Novemebr 2011) numerical abundances and species richness were significantly higher across transects compared to those for May and September. A slight difference in zooplankton abundance was observed between USC (495,556 ± 48,307 ind.m^{-2}) and WIC (453,810 ± 71,014 ind.m^{-2}) which may be related to extension of the area with cages to cover the upstream site (USC). A non significant increase in numerical abundance was observed downstream. Similarly the November survey (4th quarter) had the highest species richness in both USC (19 ± 0.3) and DSC (17 ± 2) compared to earlier three quarters of 2011. The 1st quarter high species richness (16 ± 0.7) at WIC declined in subsequent samplings to depressed species richness and numerical abundance at this site compared to the other two sites (USC and DSC). Generally rotifers were dominant in terms of species richness, (39 – 59%) compared to copepods (29 – 37%) and Cladocera (10 – 24%).

Twenty six (26) macro-invertebrate groups were recorded and as in previous surveys and key components were mollusks (Bilvavia and Gastropoda), mayflies (Ephemeroptera), two-winged flies (Diptera) and caddis flies (Trichoptera). Diptera, had the highest diversity (10 taxa) as in the previous surveys. Distribution and abundance patterns followed a comparable trend to the previous surveys with the highest total mean densities (3137 & 2087) occurring at WIC. Dipterans and the gastropods constituted the most abundant taxa particularly at WIC with mean densities of 1275 and 840 ind. m^{-2} respectively. Notably, the EPTs occurred only at USC and DSC and were absent at WIC.

A total of 12 fish species (8 haplochromines (Nkejje) and 4 non-haplochromines), belonging to 5 families were recorded in the vicinity of the cages. Haplochromines dominated the catch contributing 49.6% of all the fishes caught. Eight species belonging to 7 genera of haplochromines were caught. Highest fish diversity 10species was observed from within the cages. Fish abundance was highest also within the cages (49.6%). Eight (8) species belonging to 7 genera of haplochromines were recognized during the survey. Highest fish species diversity (7 species) was recorded from within the cages (WIC) although the largest amount of fish (57%) was from downstream the cages (DSC). The most abundant haplochromines still belonged to the genus *Astatotilapia* (76.7%) followed by *Psammochromis* (11.7%) and *Paralabidochromis* (3.3%). Haplochromines registered the highest catch rates (25.8 and 300g by numbers and weight respectively). Overall mean rates during the period under review (November 2011) were calculated at 8.5fish and 226g per net by numbers and weight respectively. Overall catch rates were higher than those calculated during the previous surveys (257 cf 226g/net/night respectively). Increase in numbers was due to increased numbers of *Synodontis afrofischeri* common during this time of the year in Napoleon Gulf.

The present observations on key environmental parameters indicate normal, expected conditions of water quality and within permissible limits recommended by NEMA. However persistent depressed zooplankton species richness and abundance together with absence of non-tolerant macro-benthos at WIC appear to suggest incipient impacts of the cage facility at the site.

1.0 Back ground

Source of the Nile Fish farm (SON) is located at Bugungu area in Napoleon Gulf, northern Lake Victoria. The proprietors of the farm requested for technical assistance of NaFIRRI to undertake regular environment monitoring of the cage site as is mandatory under the NEMA conditions. As the SON is a key collaborator/client of the institute, NAFIRRI agreed to undertake the assignment subject to facilitation by the client. The institute agreed to conduct quarterly surveys of key environmental parameters at the site including selected physical-chemical and biological factors, nutrient status, column depth, water transparency and sedimentation. Samples and field measurements were to be taken at 3 sites: within and/or close to the fish cages (WIC), upstream (USC) and downstream (DSC) of the cages.

The first environmental monitoring survey was undertaken in February 2011; the second in May 2011 and the third in September 2011. The surveys cover physical-chemical parameters, nutrient status, invertebrate and fish communities. The present report presents field observations made for the fourth quarter survey undertaken in November 2011 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 at and around the cage site including natural fish communities.

2.0 Study area

Source of the Nile Fish Farm is a fish cage rearing facility located at Bugungu area at the western end of the Napoleon gulf in northern Lake Victoria (Fig. 1). The farm is a few kilometers south of the Source of the River Nile (hence the name of the fish farm!) and is presumably influenced by the headwaters of the River Nile as it flows downstream to the nearby Owen Falls and Nalubaale Dams. The farm comprises a number of fish cages arranged in rows in a west-to-east formation, anchored by weights and buoyed by large rubber floaters. The water depth ranges from 3.2 to 8.3m with a mean depth of 4.7m. During the third and fourth quarters of 2011, the number of cages at the site has progressively increased and currently covers the USC site.

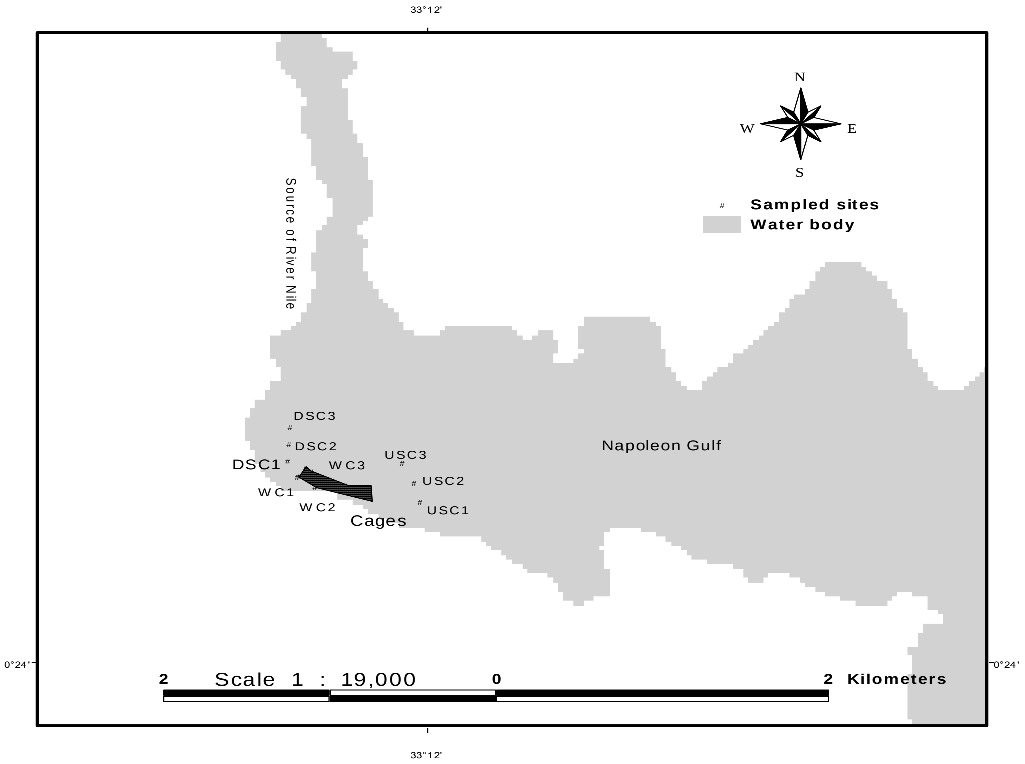


Figure 1. Map of the study area showing location of SON Fish Farm and study areas: USC- upstream of cages; WIC- within cages and DSC- downstream of cages, in northern Lake Victoria.

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 field 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, recorded and used to prepare a site locations 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 (NH3-N) and Nitrite-nitrogen (NO2-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).

3.4 Micro-invertebrates/zooplankton and Macro-invertebrates/macro-benthos

Zooplankton samples were collected with a conical net of 0.24m diameter and 60 µm mesh. The 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 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 introduced on to 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; Koste 1978. Members of each species were enumerated and recorded.

Generation of macro-benthos data involved taking sediment samples with a Ponar grab (open jaw area, 238cm^2). Three hauls were taken from each sampling point. The bottom type and texture was described from the grabbed contents. Each sample hauls was concentrated placed in clean, labeled sample bottle, and preserved with 5% formalin.

In the laboratory, each sample was rinsed with tap water and placed on a white plastic tray. Benthos were sorted from the sediment using forceps and individual taxa examined under a dissecting binocular microscope at x 400 magnification and taxonomically identified using identification 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 on 21st, 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 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) was (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 gut cavity.

4.0 Results and inferences

4.1 Water column depth and transparency characteristics at the study site

A graphical presentation of the total and Secchi depths at Source of the Nile cage culture sites as observed during the four sampling periods (November, September, May and February 2011) showed a slight variation in total depth at the three sites (USC, WIC and DSC). Upstream of the cages (USC) was the deepest site while WIC was the shallowest.

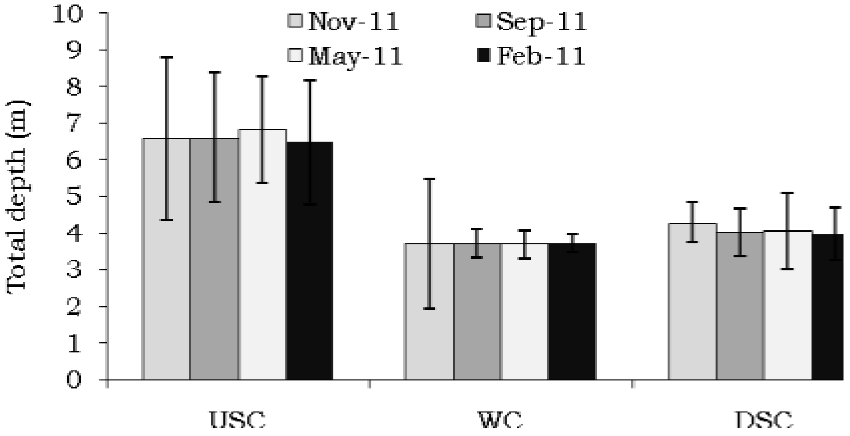


Figure 2. Comparison of total depths (mean ± Stdev; n = 6 for USC and WC; n = 7 for DSC) across sampling dates in 2011.

Water column depth (TD) ranged from 2.7 to 8.4m. Overall mean total depth ranged from 4.71 ± 1.6 in February to 4.82 ± 1.76m recorded in November.

Secchi depth (SD), a measure of water transparency based on suspended matter in water column varied from 0.87 to 1.93m (Fig.3). SD was comparably lower (<1m) across sites in November compared to other sampling times and varied within narrow limits between February and September. Average SD varied from 0.99 to 1.73m.

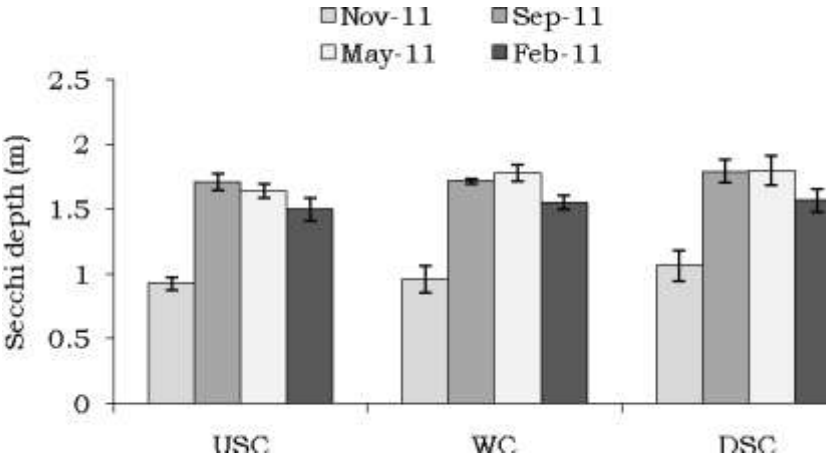


Figure 3. Comparison of Secchi depths (mean ± Stdev; n = 9) across sampling sites and dates, 2011**.**

SD was lowest at USC and highest at WC and DSC respectively. Such contrast in SD measurements could be partly attributed to the level of turbidity within the water column caused by suspended sediments in the water column capable of releasing nutrients that causes algal blooming (Mwebembezi et al, 2005). Also high phytoplankton biomass has a similar effect. Both phenomena cause lowering of the surface water clarity.

Secchi Depth measurements across sampling months show that the water was clearer at DSC compared to WC and USC although such differences do not appear to be significant. Clearer water at WIC where fish feeds are added and where fecal matter from the caged fishes is presumably high is an indication of proper cage management and probably efficient flushing effect of water currents in the cage area as well as proper management of un-utilized feeds (BMP, 2004). At SON the floating fish feed although rich in organic matter and nutrient content are readily consumed by the fish and the remnants probably drift off downstream leaving clear water. Therefore, sedimentation or re suspension of sediment materials into the water column due to fish feeds could be minimal and this may explain higher than expected SD at WIC. It is notable that an area where sedimentation has taken place a condition of anoxic sediment, with high sediment oxygen demand may be created (R.S.S. Wu R.S.S et al, 1994).

4.2 Nutrient status

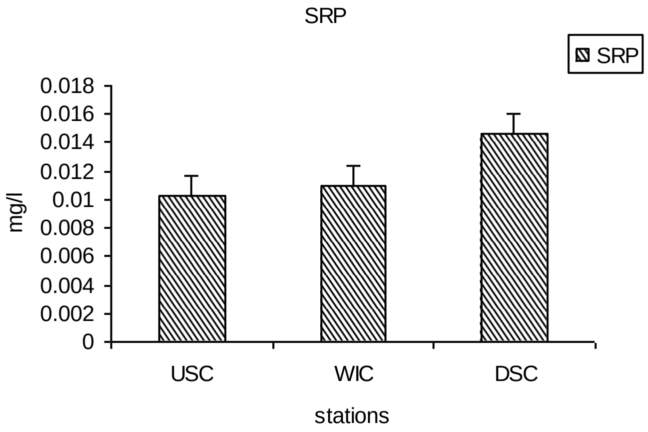


Figure 4. Soluble Reactive Phosphorus across study sites at SON cage area, November 2011.

Soluble reactive phosphorus concentrations generally varied within narrow limits (0.001-0.004 mg/l) across the three study sites and progressive increased from USC through WIC to DSC (Fig. 4). Soluble reactive phosphorus (SRP) increased downstream (0.0147mg/l when compared to that upstream (0.01mg/l) probably through its release from bottom sediments (Wetzel 2001, Kisand & Noges, 2003) although this trend does not appear to be significant.

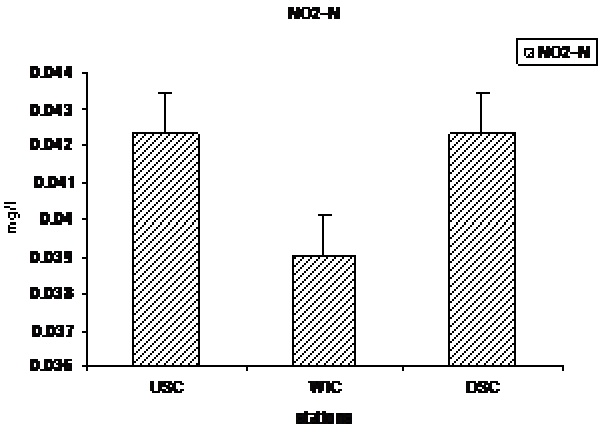


Figure 5. Nitrite-nitrogen across study sites at SON cage area, November 2011.

Nitrite nitrogen also varied within narrow limits (0.04-0.043 mg/l) but was significantly higher and comparable at USC and DSC in relation to WIC (Fig.5). The lower nitrite-nitrogen levels within the cages could probably be due to denitrification by bacteria acting on any uneaten feeds (if any) and excreted products of fishes beneath the cages or due to the continuous recycling between the different forms within the system (Rabalais, 2002).

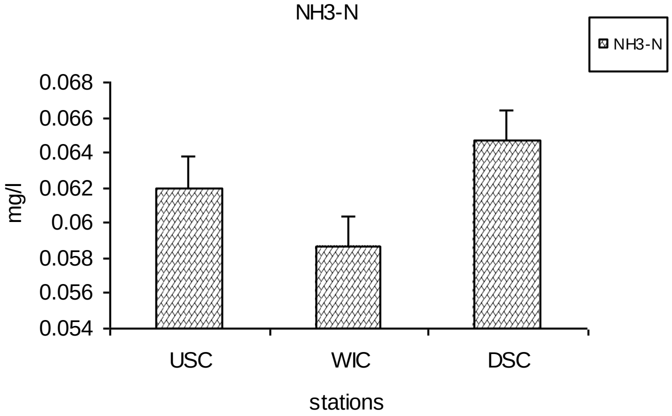


Figure 6. Ammonia-nitrogen across study sites at SON cage area, November 2011.

Similarly, Ammonium-nitrogen (Fig. 6) varied within narrow limits but was highest at DSC (0.066mg/l) and lowest at WIC (0.058mg/l). The low ammonia-nitrogen within cages (WIC) was probably due assimilation by planktonic algae and cyanobacteria (Hargreaves, 1998; Bronmark & Hansson, 2005**).**

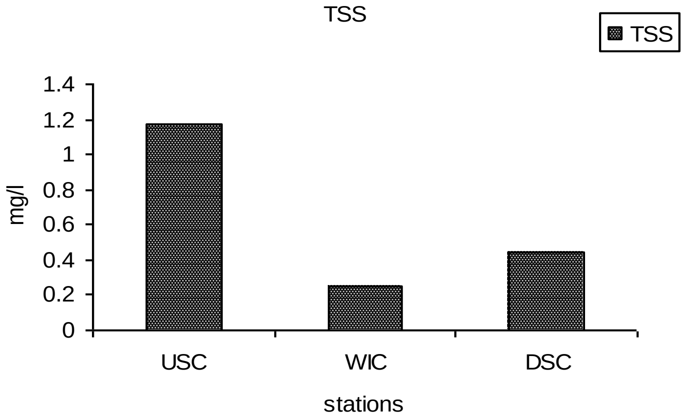


Figure 7. Total Suspended Solids across study sites at SON cage area, November 2011.

Total suspended solids (Fig. 7) were lower at WIC (0.2 mg/l) and DSC (0.4 mg/l) compared to USC (1.2 mg/l). High TSS upstream was probably due to erosion from the surrounding farm lands as observed elsewhere (Walmsley, 1980).

According to Boyd (1996), the ammonia level of (0.01-0.05mg/l) is considered safe and nitrite levels of (1 or 2 mg/l) harmful to fish and other aquatic organisms**.** The permissible levels by NEMA are (ammonia - nitrogen: 10mg/l, nitrite-nitrogen: 2 – 20mg/l, soluble phosphorus: 5.0mg/l and total suspended solids: 100mg/l) respectively. Therefore from the results above, the levels of the nutrients were below the maximum permissible limits.

4.3 Zooplankton community

Species richness and frequency of occurrence

A total of 27 species were recorded in all sites sampled. Within cages (WIC) had the lowest species number (19) compared to 25 (DSC and (USC) , with rotifers having the highest number of species (Table 1) in all sites: (WIC (9), DSC (13) and USC (10). Copepods were widely distributed in all sites compared to Rotifera and Cladocera (Table 1). Dominant Copepoda species were *Tropocyclops tenellus*, *Tropocyclops confinnis, Thermocyclops neglectus and Thermodiaptomus galeboides* exhibiting numerical densities of >10,000 ind.m^{-2} and with 100% frequency of occurrence in all sample sites. Rare copepods included *Thermocyclops incisus* and *Mesocyclops* sp. with numerical densities of <1000 ind.m^{-2} and sometime not recorded at all (Table 1). Dominant Cladocera were *Ceriodaphnia cornuta*, *Moina micrura* and *Diaphanosoma excisum* with relatively high frequent of occurrence (>60%) and numerical abundance (>1000 ind.m^{-2}). Rare cladocerans were *Chydorus* sp. and *Daphnia lumholtzi*. Eight rotifer species (*Keratella tropica*, *Lecane bulla, Brachionus angularis, Euclanis, Filinia opoliensis, K. cochlearis, Trichocerca cyclindrica* and *Sycheata* sp.) were dominant exhibiting high frequency of occurrence (80-100%) in most and sites (Table 1). The foregoing trends were generally consistent over Q1 to Q4 of 2011.

Table 1: Zooplankton temporal distribution across transects, Q1-Q4 2011at SON cage area. Key: * = <1000, ** = >1000, *** = >10,000 ind.m-2 and A = absent

	Feb-11			May-11			Sep-11			Nov-11		
Transects	**USC**	**WC**	**DSC**	**USC**	**WC**	**DSC**	**USC**	**WC**	**DSC**	**USC**	**WC**	**DSC**
Copepoda												
Thermocyclops incisus	A	A	A	*	*	**	A	*	A	*	A	*
Mesocyclops sp.	**	*	**	*	A	A	*	A	*	**	A	**
Thermocyclops emini	**	**	**	*	*	*	**	**	**	**	**	A
Thermodiaptomus galeboides	***	***	**	***	**	**	**	**	**	***	**	**
Thermocyclops neglectus	***	***	***	**	*	***	**	**	**	***	**	***
Tropocyclops confinnis	***	***	***	**	**	**	**	***	***	***	***	***
Tropocyclops tenellus	***	***	***	***	***	***	***	***	***	***	***	***
Cladocera												
Chydorus sp.	*	A	A	A	A	A	A	A	A	A	A	A
Daphnia lumholtzi (helm)	A	A	*	A	A	A	*	A	A	*	A	A
Moina micrura	*	A	*	**	*	**	**	*	*	**	A	A
Ceriodaphnia cornuta	*	**	*	*	*	**	**	**	**	**	A	*
Bosmina longirostris	**	**	*	**	*	**	**	*	A	**	**	**
Diaphanosoma excisum	**	**	**	**	*	**	*	A	A	**	**	**
Rotifera												
Ascomorpha sp.	A	A	A	A	A	A	A	*	A	A	A	A
Asplanchna sp.	A	A	A	*	A	*	*	A	A	A	A	*
Brachionus angularis	**	**	**	**	**	*	**	*	**	**	**	**
B. budapestinensis	A	A	A	*	A	A	A	A	A	A	A	A
B. calyciflorus	A	*	**	A	*	*	A	A	*	**	**	**
B. falcatus	*	*	A	A	A	A	A	A	A	*	*	*
B. forficula	*	A	*	A	A	A	A	A	A	A	A	*
B. patulus	A	A	A	*	A	A	A	A	A	A	A	A
Euclanis sp.	**	*	A	*	*	*	*	**	*	***	**	**
Filinia longiseta	**	*	**	*	A	A	*	A	*	**	**	**
F. opoliensis	**	**	**	**	**	**	**	*	A	**	A	A
Hexathra	A	A	*	*	*	A	*	*	A	A	A	**
Keratella cochlearis	*	*	*	*	*	A	**	**	**	**	**	A
K. tropica	**	**	**	***	**	***	**	**	**	**	**	**
Lecane bulla	**	A	*	**	**	**	**	**	**	***	***	***
Polyarthra vulgaris.	*	*	A	*	*	**	**	*	*	A	A	**
Synchaeta pectinata	A	*	A	A	A	A	A	*	A	A	A	A
Synchaeta sp.	*	**	*	***	**	**	**	*	**	A	A	**
Trichocerca cylindrica	**	**	**	**	**	**	**	*	**	***	***	***

November (4th quarter) numerical abundances and species richness were significantly higher across sites compared to May and September (Fig. 1). There was a slight difference in abundance between USC (495,556 ± 48,307 ind.m^{-2}) and WIC (453,810 ± 71,014 ind.m^{-2}) and this near similarity could have been due to extension of the area with cages to cover the upstream site (USC). A non significant increase in abundance was observed downstream (DSC). The November survey (4th quarter) had the highest species richness in both USC (19 ± 0.3) and DSC (17 ± 2) compared to other three quarters (Fig. 8). Though the 1st quarter showed highest species richness (16 ± 0.7) at WIC site, the trend in subsequent samplings shows a depressed species richness and numerical abundance at this site compared to the other two sites (USC and DSC) (Fig. 8). Notably, the 1st and 4th quarters exhibited significantly higher zooplankton densities in all transects compared to 2nd and 3rd quarters (Fig. 8) suggesting possible seasonality of abundance.

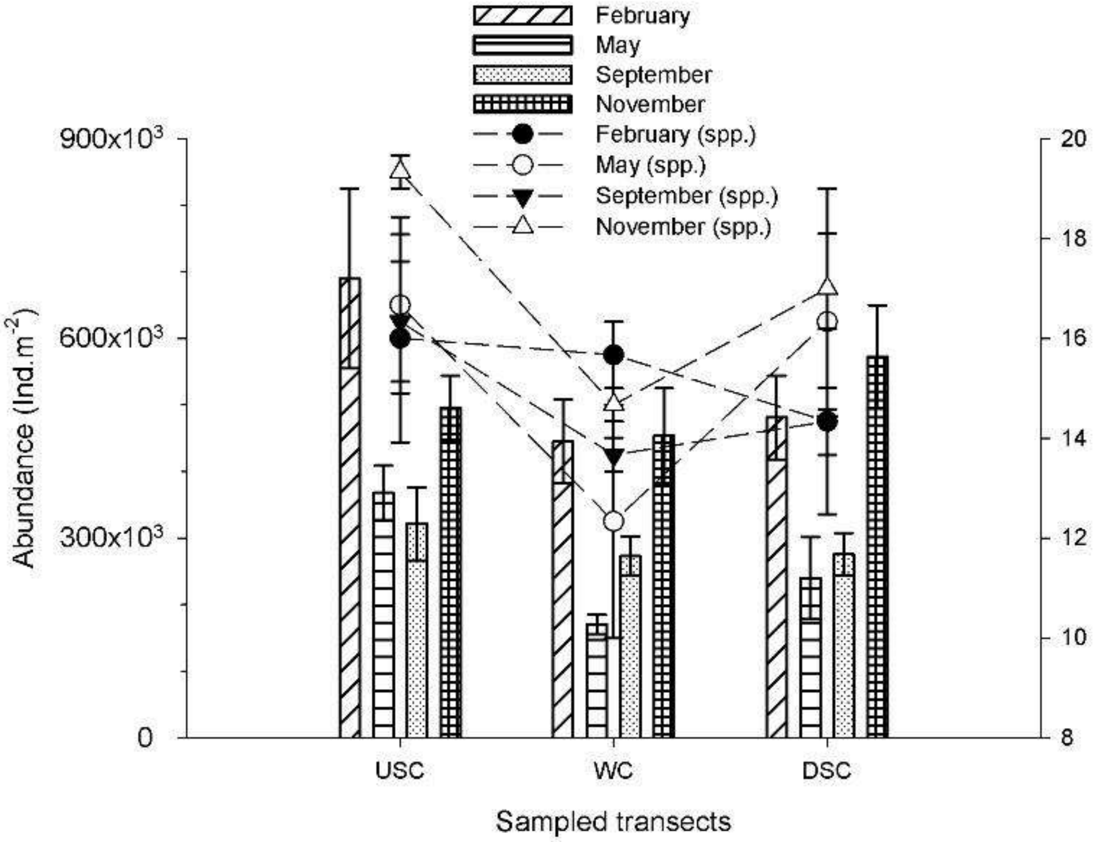


Figure 8: Temporal data for abundance and species richness across transects (USC, WIC and DSC) at SON fish farm in Napoleon Gulf, northern Lake Victoria; February to November 2011.

Generally, copepods were the dominant group in terms of relative densities (80% - 98%) compared to rotifers (1.4 – 18%) and cladocerans (0.3 – 1.7%). On the other hand rotifers were dominant in terms of species richness, (39 – 59%) compared to copepods (29 – 37%) and Cladocera (10 – 24%) (Fig. 9).

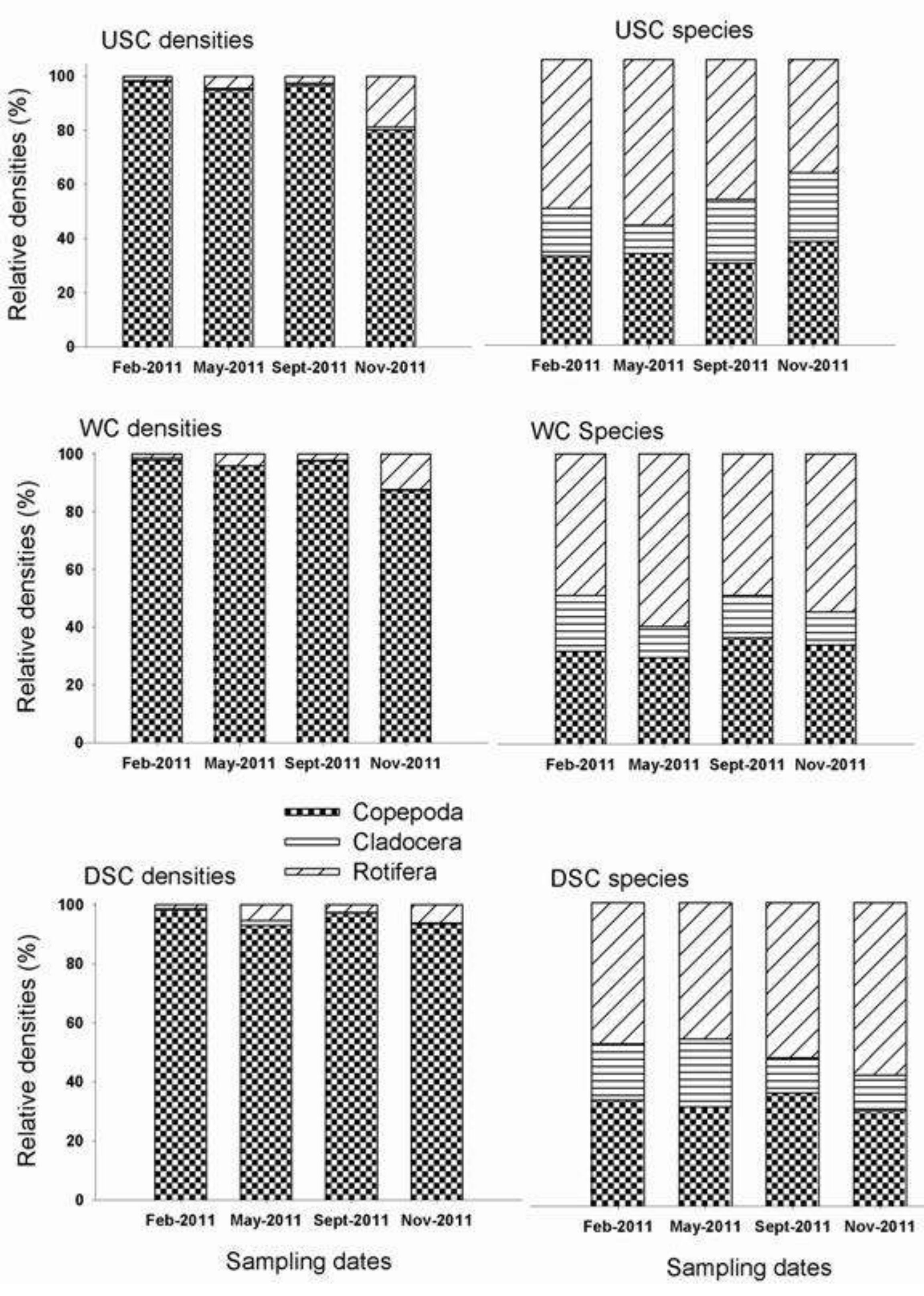


Figure 9: Relative densities and species number across sampled dates at SON cage site in Napoleon Gulf, northern Lake Victoria, 2011.

The November 2011 trends of zooplankton total densities do not deviate much from those of the previous quarters (February, May and September), but show an increase in abundance when compared to 2nd and 3rd quarters. This increase in abundance could have been a result of the extended heavy rainy season experienced during the fourth quarter (October to December) coupled with extension of cage area to cover the USC site. These phenomena may increase nutrient loading and to some extent promote eutrophication and pollution. In cage-culture, the solid wastes (uneaten food, feces and mucus) and soluble wastes (phosphorus and nitrogen compounds) are dispersed directly into the water; the amount of which will depend on the stocking density of fish, while rains accelerate surface run off from the hinterland that cause pollution and eutrophication (Lungayia et al. 2001).

Eutrophic water bodies are commonly characterised with high phytoplankton productivity (algal blooms), fluctuations in pH, dissolved oxygen and conductivity levels, as well as 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 especially in phytoplankton composition and productivity, are 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 alter zooplankton size structure largely because most zooplankton species are largely algal herbivores (Gosselain et al., 1998, Gowen et al., 1992, Steiner, 2003).

The slight increase of relative percentage composition of rotifers observed in the 4th quarter (Fig. 9), may represent ecosystem response to changes in nutrient status, resulting from sources discussed above. Dias et al. (2011) found higher abundances of zooplankton at reference sites compared to the sites with cages and only rotifers showed higher abundance near cages, this was attributed to the influence of availability of food around cages.

The persistent depressed species richness and abundances at the WIC in comparison to upstream (USC) and downstream (DSC) sites, may imply incipient cage culture impacts on the zooplankton community. This is an area of operation where fish densities are high probably causing predation pressure and high ammonia and nitrite due to excretion (Mwebaza-Ndawula, 1994, Pace, 1986, Zanatta et al., 2010). Observed rare organisms especially *Thermocyclops incises*, *Mesocyclops* sp. and daphnids could be a pointer to selective predation pressure (Brooks and Dodson, 1965) although these zooplankton species are known to be generally at low abundance in Lake Victoria.

4.6 Macro-benthic community

4.6.1 Composition

The total number of taxa encountered from the three sampling areas (USC, WIC and DSC) over the four surveys of 2011 (February, May, September, and November) were 24, 21, 26 and 27 respectively (Table 2) indicating minimal seasonal fluctuations. The macro-benthos comprised the following groups: Bivalvia and Gastropoda (Mollusca); Ephemeroptera (mayflies) Diptera (two-winged flies) and Trichoptera (caddis flies). Others were the Hirudinea (leeches) and Oligochaeta (earth worms) together belonging to phylum Annelida (Table 2).

Table 2. Composition/occurrence of the individual taxa of macro-benthos in the sampled areas at the SON farm – February, May September, November 2011. Key: P = present

Station	**USC**				**WIC**				**DSC**			
	Feb.	May	Sep	Nov	Feb	May	Sep	Nov	Feb	May	Sep	Nov
Bivalvia												
Byssanodonta parasitica	P	P		P	P			P	P		P	
Caelatura monceti								P				P
Caelatura hauttecoeuri				P								P
Corbicula africana	P		P		P	P	P	P		P	P	
Aspatheria sp.			P				P					
Mutera sp.				P				P				
Gastropoda												
Bellamyia unicolor	P	P	P	P	P	P	P	P	P	P	P	P
Biomphalaria sp.						P	P	P				
Bulinus sp.								P		P	P	
Gabbia sp.	P				P		P	P	P	P	P	P
Melanoides sp.	P	P	P	P	P	P	P	P		P	P	P
Anisus natalensis											P	
Lentorbis junodi		P								P		
Ephemeroptera												
Caenis sp.	P	P	P	P			P				P	
Povilla adusta	P	P		P					P	P	P	P
Leptophlebidae	P										P	
Heptageniidae											P	
Tricorythodes sp.									P			
Trichoptera												
Leptoceridae	P	P		P					P			
Polycentropus sp.	P	P	P	P					P	P	P	P
Diptera												
Ablabesmyia sp	P	P	P		P		P	P	P	P	P	
Chironomus spp.	P			P	P	P	P	P		P	P	P
Clinotanypus sp.					P	P	P	P		P	P	
Cryptochironomus sp.	P		P	P			P					
Procladius sp.				P	P			P			P	
Tanypus sp.					P		P	P			P	
Tarnytarsus sp.			P	P	P		P	P	P	P	P	P
Chironomidae	P	P	P	P	P				P		P	P
Ceratopogonidae					P	P	P	P				
Chaoborus sp.	P	P	P	P	P	P	P	P				P
Others												
Caridina nilotica									P			
Libellulidae								P				

The following molluscan taxa: *Byssanodonta prasitica* and *Corbicula africana* (Bivalvia); *Bellamya unicolor*, *Biomphalaria, Bulinus sp, Gabbia humerosa, Melanoides tuberculata* (Gastropoda) were common and recorded in all four quarters of 2011.

Dipteran elements (*Ablabesmyia sp., Chironomus sp., Clinotanypus sp, Cryptochironomus sp, Tanypus sp, Procladius sp, Tanytarsus sp., Chaoborus sp.* and Chironomidae and Ceratopogonidae) maintained the highest diversity with 10 taxa in all except in the May (2nd quarter) survey.

Ephemeropterans were composed of 2 spieces (*Povilla adusta* and *Caenis sp*.) in all surveys, but additional Leptophlebidae and Heptageniidae were encountered in September (3rd quarter) and *Tricorythodes sp* in February (1st quarter). Trichoptera was represented by two taxa (*Polycentropus sp* and Leptoceridae) in all the 4 quarters.

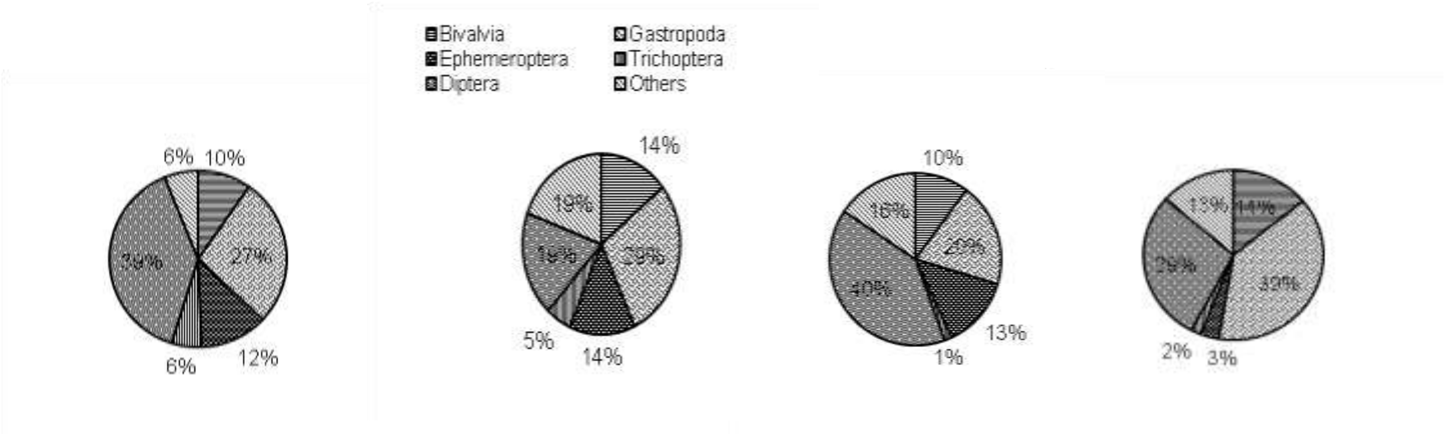


Figure 10: Left to right; Percentage composition of broader groups of macrobenthos at SON cage farm for February, May September and November 2011

4.6.2 Distribution and abundance

The distribution and abundance of macro-benthos followed a comparable trend in all the four quarters with the highest total mean densities being recorded in the WIC (1639, 3137, 2087, and 3165 ind. m^{-2} for September, May and February respectively) followed by the USC (873, 1989, 1611, 1555 ind. m^{-2}) and lowest in the DSC with 327, 1029, 560 and 1176 respectively for September, May and February (Figure 11). Dipterans and gastropods were the most abundant benthos, particularly at WIC with, mean densities of 1275 and 840 ind. m^{-2} respectively in September, a general trend observed in the other surveys (Figure 11).

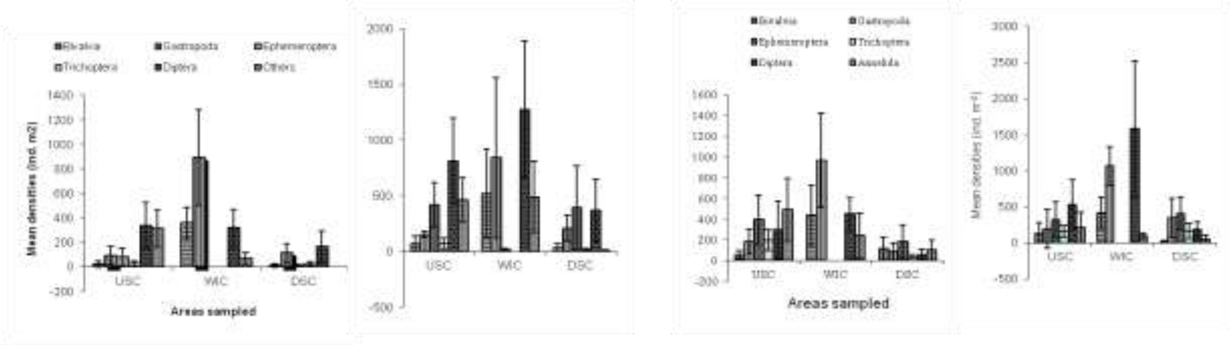
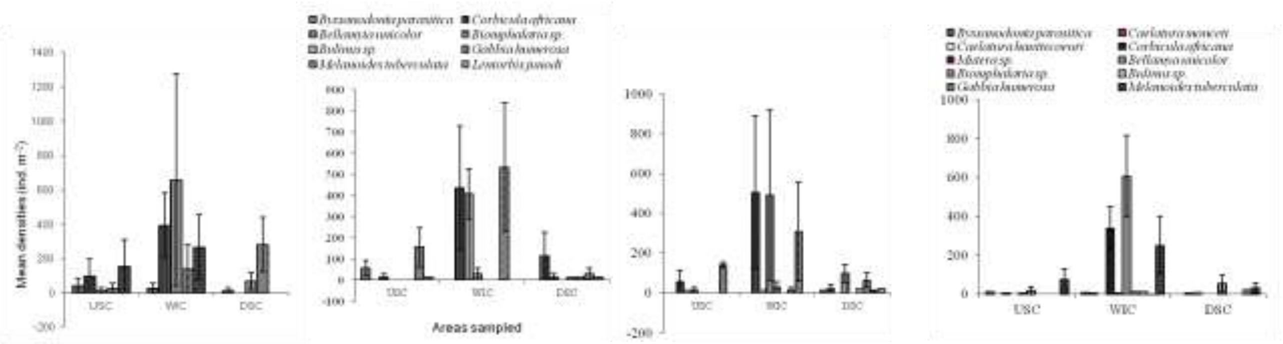


Figure 11: Composition & abundance of major macro-benthos taxa upstream cages, within cages and downstream cages ; L – R, February, May September & November-2011

In all four sampling periods, there were no trichopterans recovered at WIC. It is noted also that there was a general reduction in the abundance of trichopteran larvae in the November (4th quarter) sampling compared to the February (1st quarter) and May (2nd quarter) results. The abundance of Annelids went up in USC and WIC to 490 ind. m^{-2} and 462 ind. m^{-2} respectively from 238 and 490 ind. m^{-2} in May and 98 and 210 ind. m^{-2} respectively. A decline of 7 ind. m^{-2} occurred in DSC down from 98 ind. m^{-2} and 56 ind. m^{-2} in May and February respectively (Fig. 11).

The 4th quarter (November) registered 10 species of mollusks compared to 9, 8 and 5 in the 3rd 2nd and 1st quarters respectively (Table 2). The most abundant molluscan species were obtained at WIC (Fig. 3). In November and February *B. unicolor* was the most abundant mollusk species with 607 and 658 ind. m-2 respectively. In September, *C. Africana* (504 ind. m^{-2}) was the dominant species at WIC along with *M. tuberculata* (532 ind. m^{-2}). *M. tuberculata* dominated the USC site in all the four surveys with 252, 140, 154, and 154 ind. m^{-2} for November, in the three areas. *M. tuberculata* was also exhibited cosmopolitan distribution in May and September, May and February respectively (Figure 11). Occurring in all the three areas and in all the surveys was *B. unicolor.* *B. unicolor*, in addition to *M. tuberculata*, *C. africana* , *B. parasitica* and *G. humerosa* occurred in all the quarters (Figure 11). *Biomphalaria* and *Bulinus* were not limited to a particular area, for example, they were respectively found in WIC (28 ind. m^{-2}) and DSC (21 ind. m^{-2}) during the 3rd surveys, but in the fourth survey had both.



(a) (b) (c) (d)

Figure 12: Composition and abundance of mollusks at the upstream of cages, within cages and downstream of cages in (a) February (b), May, (c) September and (d) November 2011.

Diptera exhibited relatively higher taxonomic diversity and abundance at WIC. The November survey registered 6 taxa in USC, 8 in WIC and 4 in DSC areas. The September sampling exhibited 5 taxa in USC, 7 in WIC and 6 in DSC. In May, 3 taxa were recorded USC and 4 taxa in both WIC and DSC while in February, they were 5, 9 and 3 taxa in USC, WIC and DSC respectively (Table 2). Notably, both *Ablabesmyia* and *Chaoborus* occurred in all three sampling areas (Table 2). *Chironomus sp*. remained the most abundant species at WIC, and with the highest mean density of 966 ind. m^{-2} compared to 364 ind. m^{-2} in May and 317 ind. m^{-2} in February. The fourth quarter (November) survey registered the lowest density i.e. 117 ind. m^{-2}. *Chaoborus* sp. the second abundant dipteran taxa, was concentrated at USC site for all the four quarters, achieving a high value of 616 ind. m^{-2} in September as was *Chironomus* sp. Nonetheless the density became quite low (271 ind. m^{-2}) in the November sampling. In all, 10 taxa were recorded in November, September and, February and 7 in May. ind. m^{-2}) (Table 1). The highest abundance was in WIC and the most abundant species being *Chironomus sp*. (Figure 13 a, b and c)

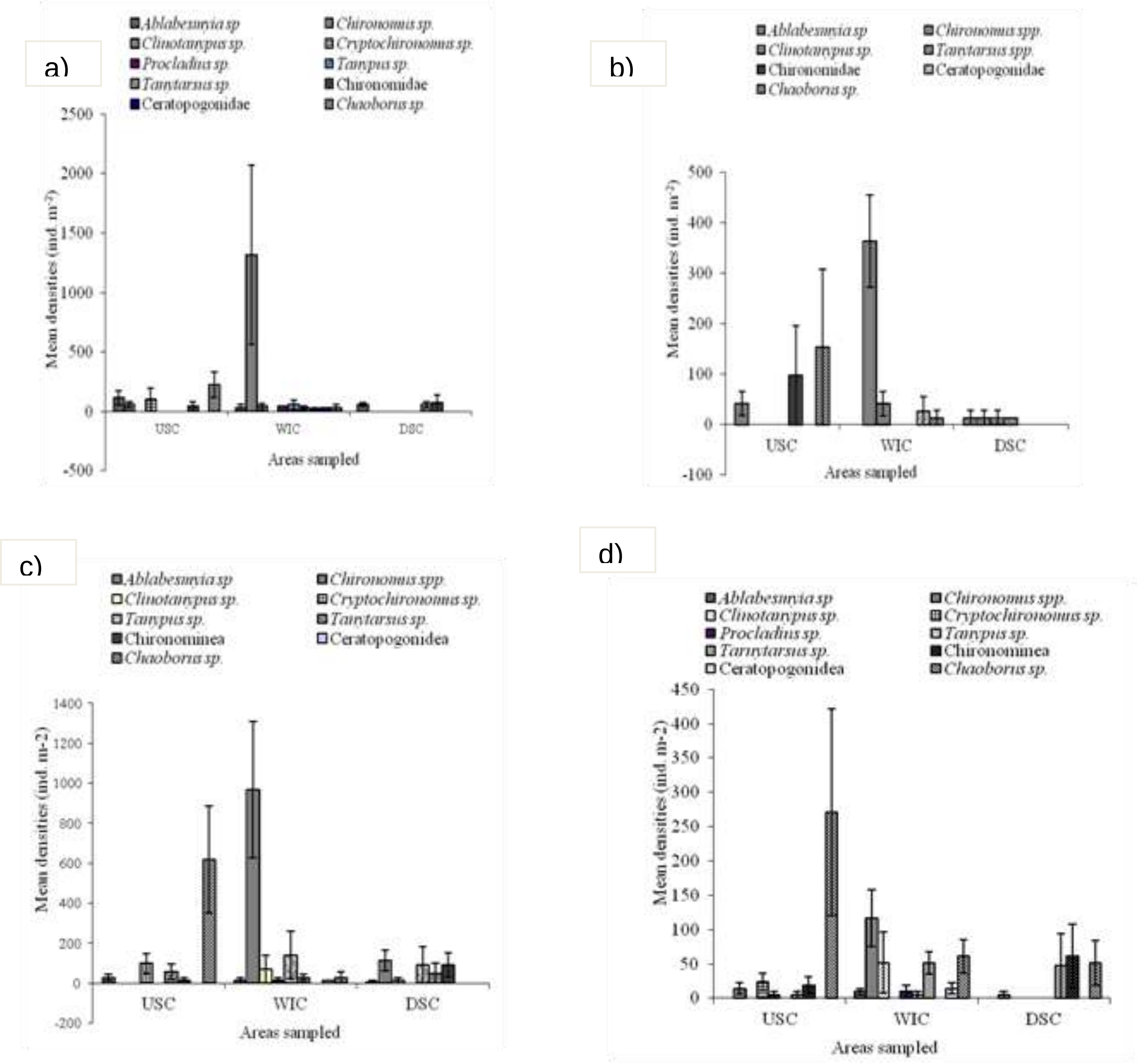


Figure 13. Composition and abundance of dipteran larvae at the upstream cages, within cages and downstream cages – (a) February, (b) May, (c) September & (d) November, 2011.

For the EPTs, only Ephemeroptera *and* Trichoptera were found; with no Plecoptera recorded. Notably the ETPs were encountered at USC and DSC but not at WIC [Fig. 14].

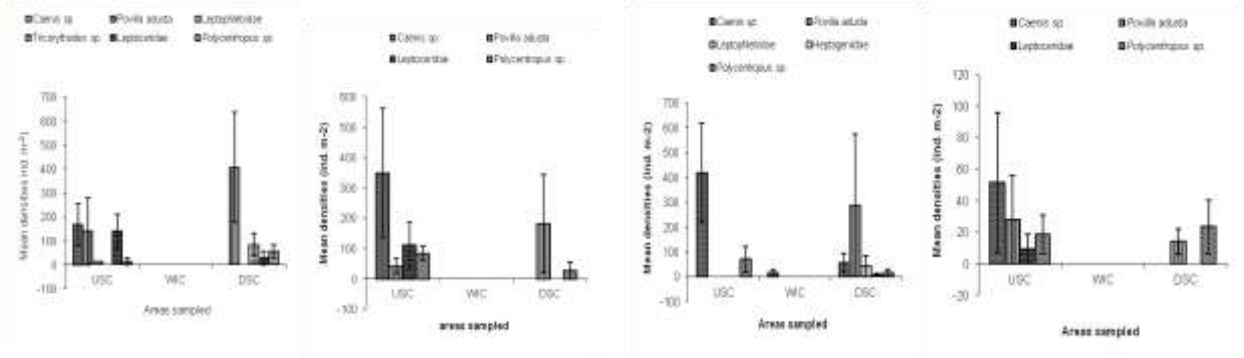


Figure14: L- R, Composition & abundance of EPTs at the upstream cages, within cages and downstream cages – February, May, September & November. 2011

Worms (annelids) were dominated by oligochaetes (Nais sp.) exhibiting, 462, 490, and 0 ind. m^{-2} for USC, WIC and DSC respectively compared to 490, 238 and 84 ind. m^{-2} in the USC, WIC and DSC respectively during the 2nd and 210, 84, and 0 ind. m^{-2} respectively during the 1st quarter (Fig. 15).

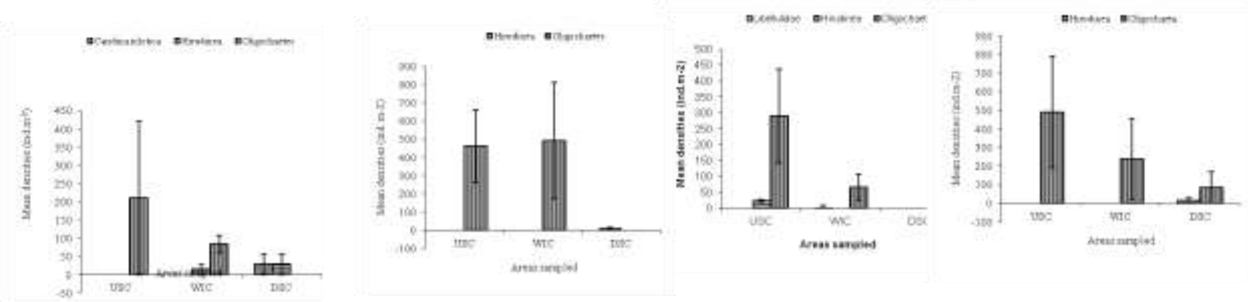


Figure 15: L – R, Composition & abundance of annelids and /or *Caridina nilotica* at the upstream cages, within cages and downstream cages –for February, May & September, 2011.

The overall total mean densities of macro-benthos remained highest in WIC (1639 ind. m^{-2} in November, 2087 ind. m^{-2} in May and ca 3100 ind. m^{-2} in Feb. and Sept). Overall lowest density estimates (327, 560, 1029 & 1176 ind. m^{-2} for November, May, September and February respectively) were recorded at DSC. (Figure 16).

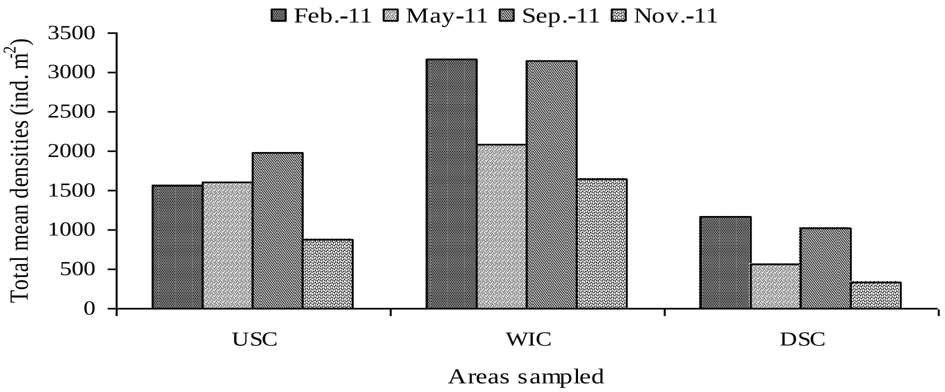


Figure 16: Total mean abundance of macro-benthos at the upstream cages, within cages and downstream cages; L – R, Feb-2011, May 2011 Sept. 2011 and Nov. 2011

In general, dipteran larvae were the predominant taxon both in terms of diversity and numerical abundance and they remained consistently pronounced at the WIC site. Ten (10) dipteran taxa were recorded in each quarter except in February (7). Their relative abundance ranged from 19% to 40% of the total mean density of macro-benthos over the four quarters. Their concentration remained relatively high within the cage area (WIC) and largely contributed by the *Chironomus* sp. Mollusks similarly remained most concentrated in the WIC area with gastropods constituting the second highest percentages of 27% 30% 20% and 39% (for February, May, September and November, respectively). Ephemeropterans had 12, 13, 13 and 3% for the 1st, 2nd, 3rd and 4th quarters respectively. Trichopterans fell within in the same range for the three quarters but notably obtained at USC and DSC. The EPTs notably, existed only in the USC and DSC, and were absent at WIC in all four quarters.

4.7 Fish community

4.7.1 Fish Catch composition

A total of 12 fish species 8 haplochromines (Nkejje) and 4 non-haplochromines), belonging to 5 families were recorded in the vicinity of the cages (Table 3). Haplochromines dominated the catch contributing 49.6% of all the fishes caught. Other fish species caught in order of numerical importance were *Synodontis afrofischeri* (Nkolongo) 41.3%, *Lates niloticus* (Mputa) 5.8%, *Mormyrus kannume* (Elephant snout fish: Kasulubana) 1.7%, and *Clarias gariepinus (*Male*) 1.7%.* Highest fish diversity 10 species was observed from within the cages (WIC) site. Fish abundance was highest also at WIC site (49.6%).

Table 3. Catch rates (numbers) of fish species from SON FISH cages obtained during the four quarters of 2011.

Sampling period			**Q1**	**Q2**	**Q3**	**Q4**
Date of sampling			Feb. 2011	May. 2011	Sep. 2011	Nov. 2011
Season			Dry	Wet	Wet	Wet
Family	Species	Site				
Centropomidae	*Lates niloticus*	USC	0.5	0.08	0.3	0.3
		WIC	0.2	0.31	0.1	0.2
		DSC	0.1	0.38	0	0.2
		All	0.2	0.26	0.1	0.2
Characidae	*Brycinus jacksoni*	USC	0	0	0	0
		WIC	0	0	0	0
		DSC	0	0.75	0	0
		All	0	0.25	0	0
Cichlidae	Haplochromines	USC	7.3	0.75	2.3	9.5
		WIC	7	1.5	58.5	1.8
		DSC	20.3	12.25	16.5	8.5
		All	11.5	4.83	25.8	6.0
	Oreochromis niloticus	USC	0	0.08	0	0
		WIC	0	0.15	0.5	0
		DSC	0.1	0.08	0.1	0
		All	0.03	0.1	0.2	0
	Tilapia zillii	USC	0.4	0	0	0
		WIC	0	0	0.4	0
		DSC	0.1	0	0.1	0
		All	0.2	0	0.2	0
						0
Clariidae	*Clarias alluaudi*	USC	0	0	0	0
		WIC	0	0	0.8	0
		DSC	0	0	0	0
		All	0	0	0.3	0
	Clarias gariepinus	USC	0	0	0.1	0
		WIC	0	0	0	0
		DSC	0	0	0	0.2
		All	0	0	0.03	0.1
Mochokidae	*Synodontis afrofischeri*	USC	0.3	0	0	0.5
		WIC	0	0	0	1203
		DSC	0	0	0	0
		All	0.1	0	0	5.0
	Synodontis victoriae	USC	0.3	0	0	0

4.7.2 The haplochromines

Eight (8) species belonging to 7 genera of haplochromines were rencountered during the fourth (November) survey (Table 3). Highest fish species diversity (7 species) was recorded from within the cages (WIC) although the largest amount of fish (57%) was from downstream the cages (DSC). The most abundant haplochromines still belonged to the genus *Astatotilapia* (76.7%) followed by *Psammochromis* (11.7%) and *Paralabidochromis* (3.3%). A number of these haplochromines such as *Paralabidochromis* and *Mbipia*) are associated with rocky or hard bottom substrates common in this area of the gulf.

4.7.3 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. In terms of both numbers and weight, catch rates were highest within the cages (4.6, 382 respectively) (Table 4). Haplochromines recorded the highest rates (25.8 and 300g by numbers and weight respectively). Overall mean rates during the period under review (May 2011) were calculated at 8.5fish and 226g per net by numbers and weight respectively.

Table 4. Catch rates by weight (g) of fish caught in SON FISH Q1 to Q4 2011

Sampling period			**Q1**	**Q2**	**Q3**	**Q4**			
Date of sampling			Feb. 2011	May. 2011	Sep. 2011	Nov. 2011			
Season			Dry	Wet	Wet	Wet			
Family	Species	Site							
Centropomidae	*Lates niloticus*	USC	118.9	1.38	138	2			
		WIC	17.8	126.3	1	5			
		DSC	3.7	8.0	0	8			
		All	46.8	45.2	46	5			
Characidae	*Brycinus jacksoni*	USC	0	0	0	0			
		WIC	0	0	0	0			
		DSC	0	34.5	0	0			
		All	0	11.5	0	0			
Cichlidae	Haplochromines	USC	96.5	19.0	35	9			
		WIC	70	10.5	520	71			
		DSC	411	243.5	345	90			
		All	192.5	91.0	300	66			
	Oreochromis niloticus	USC	0	5.2	0	0			
		WIC	0	9.9	79	0			
		DSC	0.9	0.5	16	0			
		All	0.3	5.2	32	0			
	Tilapia zillii	USC	38.3	0	0	0			
		WIC	0	0	3	0			
		DSC	2.3	0	12	0			
		All	13.5	0	5	0			
Clariidae	*Clarias alluaudi*	USC	0	0	0	0			
		WIC	0	0	17	0			
		DSC	0	0	0	0			
		All	0	0	6	0			
	Clarias gariepinus	USC	0	0	147	0			
		WIC	0	0	0	0			

		DSC	0	0	0	308			
		All	0	0	49	108			
Mochokidae	*Synodontis afrofischeri*	USC	5	0	0	26			
		WIC	0	0	0	597			
		DSC	0	0	0	0			
		All	1.7	0	0	244			
	Synodontis victoriae	USC	21.5	0	0	0			
		WIC	0	0	0	0			
		DSC	0	0	0	0			
		All	7.2	0	0	0			
Mormyridae	*Mormyrus kannume*	USC	32.3	61.1	6	0			
		WIC	0	0	0	172			
		DSC	0	0	0	0			
		All	10.8	20.4	2	60			
Overall Rates		USC	212.6	73.5	302	8			
		WIC	39.4	139.4	246	382			
		DSC	132.5	94.0	129	343			
		All	128.2	102.3	226	257			
No of species recovered		USC	12	5	4	3			
		WIC	5	4	5	4			
		DSC	8	8	3	3			
		All	16	11	7	5			

Table 5. Percent contribution (by numbers) of haplochromine species from SON FISH cages obtained during the first two quarters of the survey.

Sampling period			Q1	Q2	Q3	Q4
Date of sampling			Feb. 2011	May. 2011	Sep. 2011	Nov. 2011
Season			Dry	Wet	Wet	Wet
Genus	**Species**	**Site**				
Astatoreochromis	*A.alluaudi*	USC	0	0	0	0
		WIC	0	0	0	1.7
		DSC	1.5	0	0.6	0
		All sites	1.5	0	0.6	1.7
Astatotilapia	*A. "thick lip"*	USC	3.6	0	0	0

		WIC		0	0	0
		DSC		0	0	0
		All sites	3.6	0	0	0
	A. "pink anal"	USC		0	0	0
		WIC		0	0	0
		DSC		60.3	0	0
		All sites		60.3	0	0
	Astatotilapia sp	USC	12.3	0	0.9	28.3
		WIC	6.5	8.6	68.3	1.7
		DSC	42.3	15.5	5.1	46.7
		All sites	60.9	24.1	74.3	76.7
Lipochromis	*L. parvidens*	USC	0.7	0	0	0
		WIC	0	0	0	0
		DSC	0	1.7	0	0
		All sites	0.7	1.7	0	0
Lithochromis	*Lithochromis sp*	USC	0	0	0	0
		WIC	0	1.7	0	0
		DSC	0	0	0	0
		All sites	0	1.7	0	0
Mbipia	*M."blue"*	USC	0.7	0	0	0
		WIC	0	0	0	0
		DSC	0	0	0	0
		All sites	0.7	0	0	0
	M. mbipi	USC	0	0	1.8	0
		WIC	0	0	0	1.7
		DSC	0	0	0	0
		All sites	0	0	1.8	1.7
Paralabidochromis	*P. "blackpara"*	USC	1.5	3.4	0	0
		WIC	0.7	0	2.1	1.7
		DSC	8.7	3.4	13.6	1.7
		All sites	10.9	6.9	15.7	3.3
	P. victoriae	USC	0	0	0	0
		WIC	0	0	0.3	0
		DSC	0	0	0	0
		All sites	0	0	0.3	0
Psammochromis	*P. riponianus*	USC	0	1.7	0	3.3
		WIC	2.2	0	0	0
		DSC	4.4	0	0.3	8.3
		All sites	6.5	1.7	0.3	11.7

Pyochromis	*Ptyochromis sp*	USC	0	0	0	0
		WIC	0	0	0	0
		DSC	2.2	0	0	0
		All sites	2.2	0	0	0
Pundamilia	*Pundamilia sp*	USC	0.7	0	0	0
		WIC	10.9	0	0	0
		DSC	0	0	0	0
		All sites	11.6	0	0	0
	P. macrocephala	USC	1.5	0	0	0
		WIC	0	0	0	0
		DSC	0	0	0	0
		All sites	1.5	0	0	0
Xystichromis	*X. "earthquake"*	USC	0	0	0	0
		WIC	0	0	0	0
		DSC	0	3.4	0	0
		All sites	0	3.4	0	0
	X. phytophagus	USC	0	0	0	0
		WIC	0	0	0	0
		DSC	0	0	0.3	0
		All sites	0	0	0.3	0
Overall Contribution		USC	21	5.2	4.5	31.7
		WIC	20.3	10.3	74.9	11.7
		DSC	58.7	84.5	20.5	56.7
		All sites	100	100	100	100
No of species recovered		USC	7	2	2	2
		WIC	4	2	3	7
		DSC	5	5	5	3
		All sites	10	7	7	8

4.7.4 Biology of common fish species

Basic biology of common fish species caught from the cage area in all quarters sampled in 2011 is summarized in Table 6. Other than haplochromines the rest of fish species were in such low numbers that not much information can be inferred from the data.

Table 6. Basic biological parameters of fish species caught SON Fish site May 2011

Sampling period	Parameter	Q1	Q2	Q3	Q4
Date of sampling		Feb. 2011	May. 2011	Sep. 2011	Nov. 2011
Season		Dry	Wet	Wet	Wet
Species					
Clarias alluaudi	Size range (cm)	0	0	13.6 – 15.1	0
	% mature	0	0	100	0
	Main food type	0	0	IR, FR	0
	Parasites found	0	0	Nil	0
	No. r examined	0	0	3	0
Clarias gariepinus	Size range (cm)	0	0	61	58
	% mature	0	0	Mature	Mature
	Main food type	0	0	ODT, FR	Stomach empty
	Parasites found	0	0	Nil	Nil
	No. r examined	0	0	1	1
Lates niloticus	Size range (cm)	10 - 45	9 - 36	9 - 51	11 - 69
	% mature	All immature	All immature	20	13
	Main food type	FR	FR	Haps 73, FR 27	Fish (Haps), mollusks
	Parasites found	Nil	Nil	Nil	Nil
	No. examined	9	9	5	8
Brycinus jacksoni	Size range (cm)	0	13 - 15	0	0
	% mature	0	All mature	0	0
	Main food type	0	ODT, IR	0	0
	Parasites found	0	Nil	0	0
	No. examined	0	3	0	0
Haplochromines	Size range (cm)	7.0 – 12.4	7.4 – 12.5	6.7 – 13.6	8.7 – 18.6
	% mature	98	74	60	100
	Main food type	IR	IR	IR	Chironomid larvae
	Parasites found (% infection)	Nematode 5	Nematode 2	10	6
	No. examined	59	43	48	16
Tilapia zillii	Size range (cm)	9 - 20	0	7 – 17	0
	% mature	75	0	25	0
	Main food type		0		0
	Parasites found		0		0

	No. examined	4	0	4	0
Mormyrus kannume	Size range (cm)	20 - 29	42	20	19 & 61
	% mature	33	100	immature	50
	Main food type	Povilla, IR	Povilla, Chiro L	IR	Povilla
	Parasites found	Nil	Nil	Nil	Nil
	No. examined	3	1	1	2
Oreochromis niloticus	Size range (cm)	9	7 - 17	7 - 28	0
	% mature	Immature	All immature	All immature	0
	Main food type	Empty	Empty	Fish feeds	0
	Parasites found	Nil	Nil	Nil	0
	No. examined	1	4	8	0
Synodontis afrofischeri	Size range (cm)	10	0	0	9.2 -14.5
	% Mature	mature	0	0	100
	Main food type	Empty	0	0	Mollusks
	Parasites found	Nil	0	0	Nematode 7%
	No. examined	1	0	0	15
Synodontis victoriae	Size range (cm)	18	0	0	0
	% mature	Mature	0	0	0
	Main food type	*Povilla*	0	0	0
	Parasites found	Nil	0	0	0
	No. examined	1	0	0	0

Catch rates were higher than those calculated during the previous surveys (257 cf 226g/net/night respectively). Increase in numbers was due to increased numbers of *Synodontis afrofischeri* common during this time of the year in Napoleon Gulf.

While it may be too early to explain fish distribution at the sites sampled, it is worthwhile noting that there was least fish upstream (USC) and that fleets set within (WIC) and downstream (DSC) yielded most fish. Although stomach contents of the fishes examined do not clearly show any of the foods supplied/fed to the farmed fish, it may be presumed that remnants of this food is swept by currents downstream and probably attracting fish in this area.

5. Conclusions

1. Sedimentation or re-suspension of sediment materials into the water column due to fish feeds appears to be minimal and this may explain higher than expected SD at WIC. There is either very minimal materials coming from the cages or if any then they are washed away by the water current.
2. All the nutrient parameters measured during the survey were found to be well below levels considered to be dangerous to fish and other aquatic organisms as they found well below the maximum permissible limits recommended by NEMA and other workers.
3. Persistent depressed zooplankton species richness and abundances at the WIC compared to upstream (USC) and downstream (DSC) may imply incipient cage culture impacts on the zooplankton community.
4. The occurrence of tolerant macro-benthos at USC and DSC and the persistent absence of non-tolerant ones at WIC observed over the study period suggest favourable water conditions at USC and DSC compared to those at WIC.
5. Current field observations on the fish community indicate still little or no effect of the fish cage facility on the wild population of fishes in this area of the lake.

6. Recommendations

1. The location of the original USC site needs to be reviewed because as the number of cages has increased especially during the third and fourth quarters of 2011, this site has also come under the area covered by cages, as such the results from this site may not represent the original intention of an a site upstream of the cages.
2. With addition of more cages at the site, and given the current observations indicating potential for impacts of the cage facility to the environment and some natural aquatic communities, regular environmental monitoring of the cage area remains a key requirement in order to keep track of possible development of undesirable impacts.

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