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 3: July-September 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 and the third quarter survey, which is the subject of this report, in September 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, including the natural fish community at and around the cage site.

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-benthos were 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.

Between 5 and 6 major algal groups occurred in the cage area of which blue- green algae was the dominant type. Higher blue- green algal biomass (36,904ug/L) was observed at WIC compared to USC and DSC (8,401-15,360ug/L); an observation which is comparable to the previous surveys. Consistent high algal biomass at WIC appears to suggest influence from the cages which have substantially increased since the first environmental monitoring of the cage site in February 2011.

Soluble reactive phosphorus (SRP) was highest (0.024mg/l) at USC with slightly lower levels at WIC and DSC; an observation indicating lower levels compared to the previous survey results. Nitrite-nitrogen levels were generally low in all stations, ranging from 0.0006 to 0.0008mgl^{-1} from USC to DSC. Ammonia-nitrogen was slightly higher (0.012mgl^{-1}) at USC compared to WIC (0.009mgl^{-1}) and DSC (0.01mgl^{-1}). Total suspended solids (TSS) increased from (0.71mgl^{-1}) at USC through (0.79mgl^{-1}) at WIC to (1.29mgl^{-1}) at DSC. In general, the observed levels of all parameters above were below those considered toxic to fish and other aquatic organisms according to Boyd (1996).

In all, twenty seven (27) zooplankton species were encountered. WIC had the lowest species range (13 – 14) compared to 12 – 18 and 14 – 18 at DSC and USC respectively. Rotifers species were numerically superior at all 3 stations. DSC had the lowest species number (12) and abundance (213,027 Ind. m^{-2}); Highest abundance was (429,739 Ind. m^{-2}) at USC. Copepods contributed the highest abundances at all stations. Dominant copepod species were *Tropocyclops tenellus, Tropocyclops confinnis, Thermocyclops neglectus* and *Thermodiaptomus galeboides*. Generally, WIC had lower numerical abundance and species richness. Current results do not deviate much from the previous trends of the first and second quarters (February and May 2011).

Twenty six (26) macro-invertebrate groups were recorded and as in previous surveys, 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 similar trend to the previous surveys with the highest total mean density (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. The EPTs occurred only at USC and DSC and were nonexistent at WIC.

Thirteeen (13) fish species (7 haplochromines/(Nkejje) and 6 non-haplochromines), belonging to 4 families were recorded with haplochromines dominating the catch (93.3%). Highest haplochromine diversity (5 species) was recorded at DSC although the largest amount of fish (95%) was from WIC. Genus *Astatotilapia* was the most abundant (74.3%) of the haplochromines. Fish catch rates by numbers were highest at WIC (19.5) while by weight highest rates occurred at USC (302g per net). Haplochromines had the highest rates with 25.8 by numbers and 300g weight. Overall mean catch rates for September 2011 were 8.5 fish and 226g per net by numbers and weight respectively. Overall fish catch rates were higher than those of the previous surveys. Increase in numbers was due to the very many haplochromines caught especially at WIC while weight was largely contributed by Nile perch, and *Clarias* and Tilapia. It is noteworthy that there was more fish at DSC and that the fleet set at WIC yielded the least amount of fish. It may be presumed that remnants of cage fish feed may have got swept by currents downstream probably attracting fish in this area.

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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 and the second in May 2011. The surveys cover physical-chemical parameters, nutrient status, invertebrate and fish communities. The present report presents field observations made for the third quarter survey undertaken in September 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 rearing cage 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.

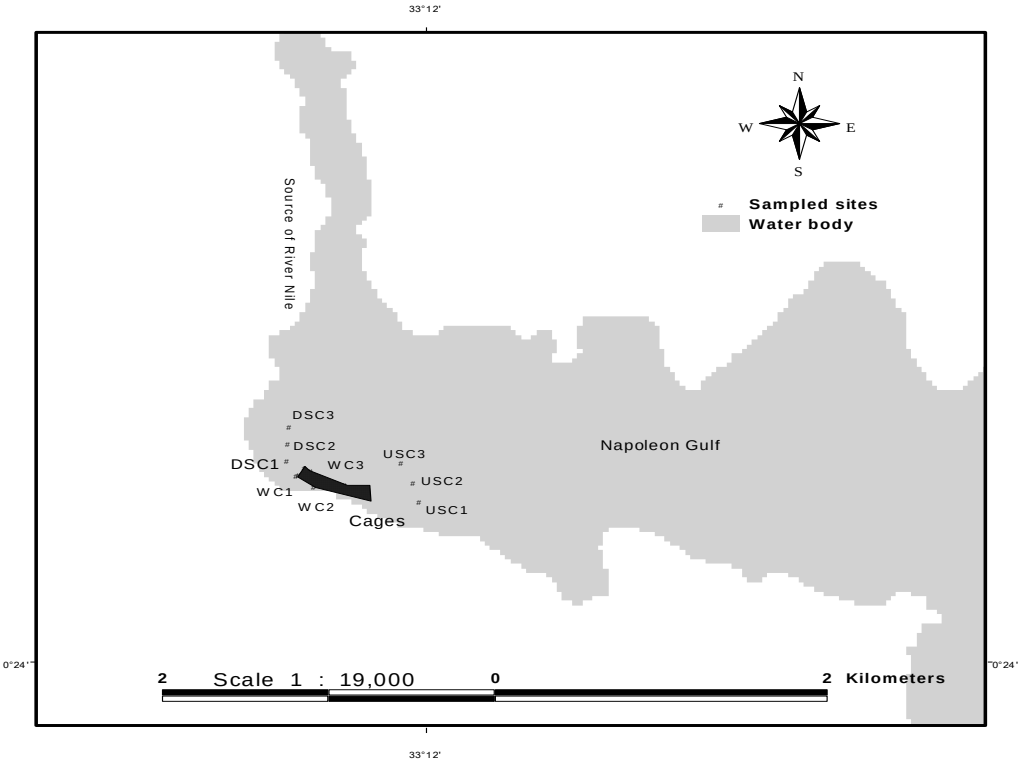

Figure 1. Map of the study area showing location of SON Fish Farm and study areas: USC- upstream of cages; WIC- within cages and DSC- downstream of cages, in northern Lake Victoria.

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, algal composition and biomass

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). Sub-samples of water were filtered on to GF filter papers for determination of algal biomass while other sub-samples were examined under an inverted microscope for the determination of algal species composition.

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 profiles and Secchi depth

Total depth ranged from 3.21 at DSC to 8.33m at USC while secchi depth ranged from 1.4 m to 1.72 m (Table 2). Mean total depth at USC was 6.47 ± 1.70 m, 3.71 ± 0.26 m at WIC and 3.97 ± 0.72 m at DSC. Secchi depth ranged from 1.4 m to 1.72 m with mean Secchi depths of 1.49 ± 0.09 at USC, 1.55 ± 0.07m at WIC and 1.56 ± 0.08 m at DSC. The lower SD at USC may have resulted from the differences in total depths (Table 1) and speed of water current relative to barriers such as the fish rearing cages.

Table 1. Total and Secchi Depths (mean ± SD) across sites at SON fish farm, September 2011.

	USC			WC			DSC			Total		
Depth	Mean	N	Std. Deviation	Mean	N	Std. Deviation	Mean	N	Std. Deviation	Mean	N	Std. Deviation
TD	6.47	9	1.703	3.71	9	0.255	3.97	9	0.716	4.72	27	1.637
SD	1.49	9	0.093	1.55	9	0.072	1.56	9	0.077	1.5	27	0.084

Table 2. Minimum and maximum Total and Secchi Depths (mean ± SD) across sites at SON fish farm, September 2011.

Depth	N	Minimum	Maximum	Mean	Std. Deviation
TD (m)	27	3.21	8.33	4.717	1.636637
SD (m)	27	1.4	1.72	1.53	0.083773

In general, TD and SD measurements in September, May and February showed comparable trends (Fig 2). The consistency of higher SD values at USC compared to WIC and DSC in February, May and September 2011 may point to higher suspended materials at the two downstream sites in relation to the cage location.

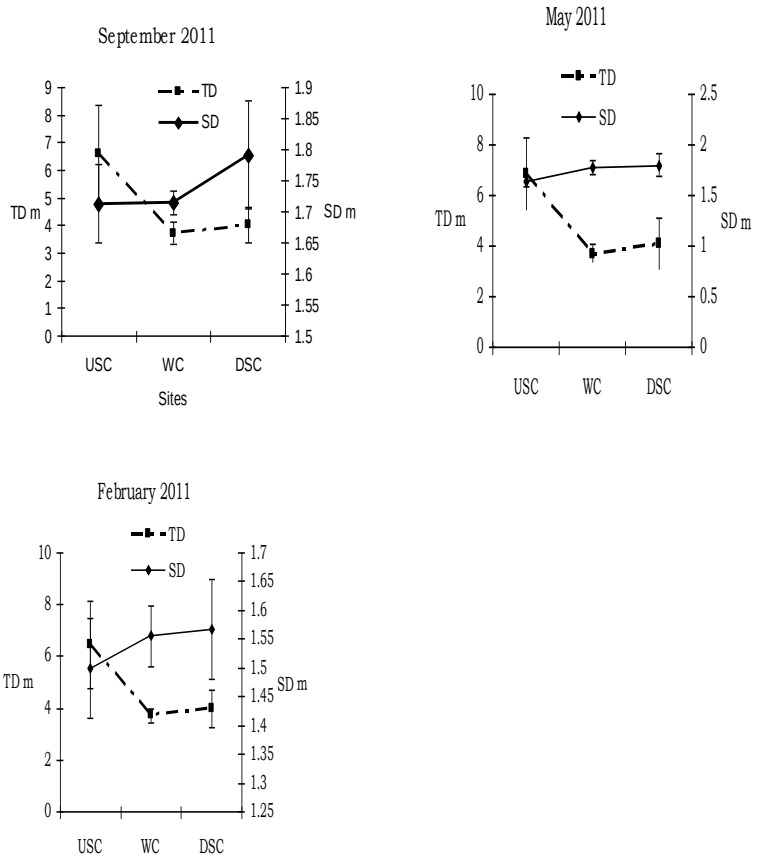

Figure 2. Total (TD) and secchi (SD) depths for September, May and February 2011 at USC, WIC and DSC in SON fish farm.

Presence of cages at WIC may act as a barrier to wave/current action, causing greater suspension of organic and other particles in the water column at this site and probably affecting the nearby downstream site (DSC) in a similar way. The observed sediment type constituted by silt mixed with organic and algal matter at WIC (see macro-invertebrate section below) indicates that temporary sedimentation may be taking place around the cages although the rate would need to be established with a sediment trap. It has been reported that sedimentation rate in Lake Victoria ranges from 100g/m2/yr to 300g/m2/yr, as such this need not be an issue to worry about except at deltas as suggested in the LVEMP (2005) report.

4.2 Algal community

Six (6) major taxonomic groups of algae (Fig.1) (Blue-green, Green, Cryptophytes, Dinoflagellates, Euglenophytes and Diatom) were encountered at WIC while at USC, Cryptophytes was missing. Blue-green algae were dominant at all sites. Higher algal

biomass (36,904ug/L) of blue-green algae was observed at WIC compared to USC and DSC (8,401&15,360ug/L) respectively (Fig. 3); a trend also observed in chlorophyll-a values (Fig. 4).

Notably, the blue-greens are a dominant algae in most of the inshore areas of Lake Victoria as reported by Mugidde (1992, 1993) and NaFIRRI (2007) as such the present results may not be attributed to the presence of the fish cages. However, the high algal biomass at within the cages site (WIC) may suggest some influence from the fish cages probably related to the increased number of cage units since the first sampling. High algal biomass could also partly result from agricultural activities in the lake catchment leading to an influx of nutrients from adjacent land as well as atmospheric deposition (Talling, 1966).

Water degradation in Africa has been recognized from the intense human activity, because of the fast increasing human population around the lake shores and / or in lake basins (Bootsma and Hecky 1993).

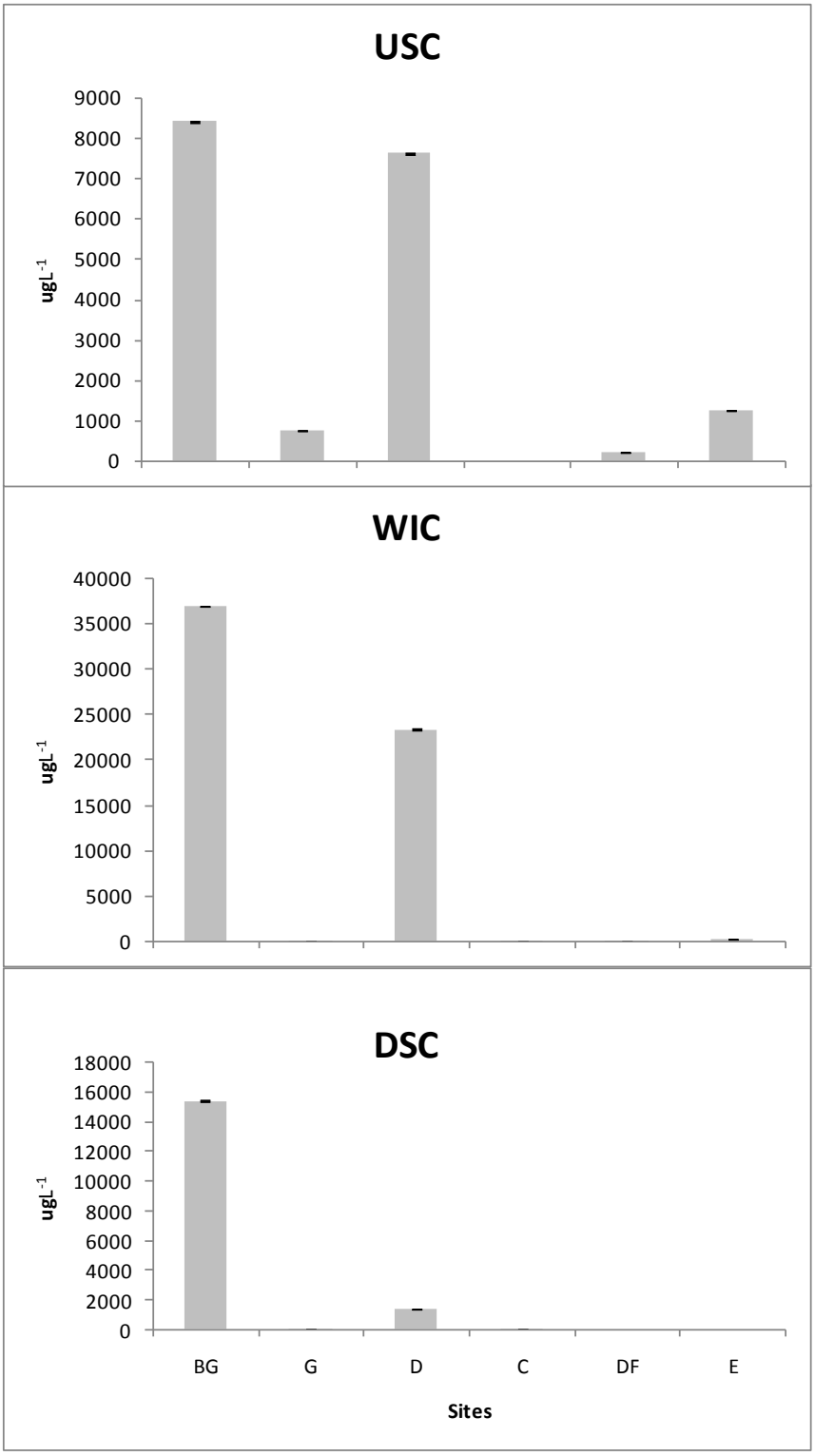

Figure . 3 Mean algal biomass (ugl^{-1}) at the three sample sites at SON fish farm, September 2011.

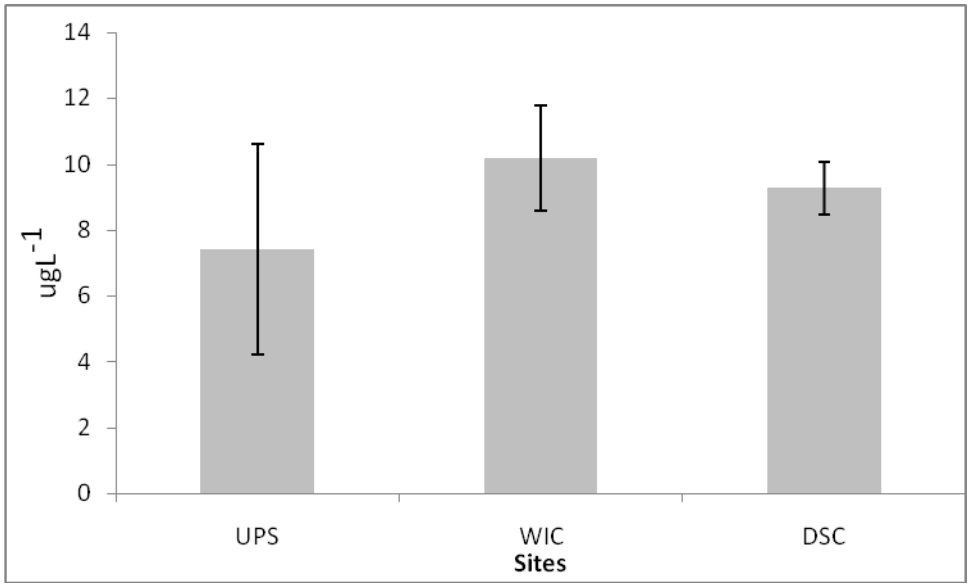

Figure 4. Mean Chrorophyll a concentration (ugl^{-1}) at the SON fish cages, September 2011.

4.3 Physical-chemical environment

Mean Dissolved oxygen was higher (6.23 mg/L) at the up stream site (USC) than down stream (DSC) and within cages (WIC) (5.9 & 5.94mg/L) respectively. These values were slighly higher than values reported in the previous survey (Figure.5). Mean water temperatures (Figure.7) were slightly higher (25.02^0 C) upstream compared to within and downstream cages (24.73 & 24.58 ^{0} C) respectively. Mean pH values (Figure.6) were comparable across all sites (7.86 upstream/USC, 7.93 within cages/WIC and 7.35 downstream/DSC).

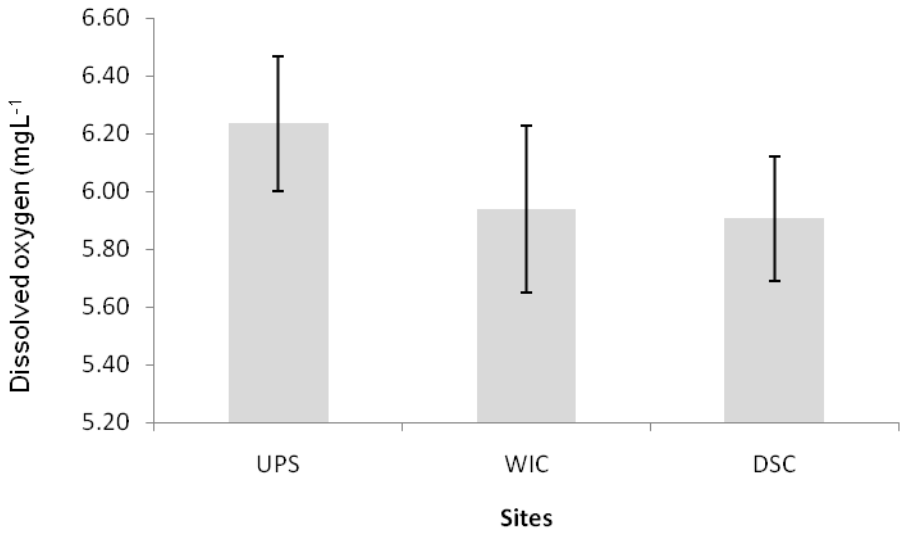

Figure.5. Mean disolved oxygen levels at SON fish farm, September 2011.

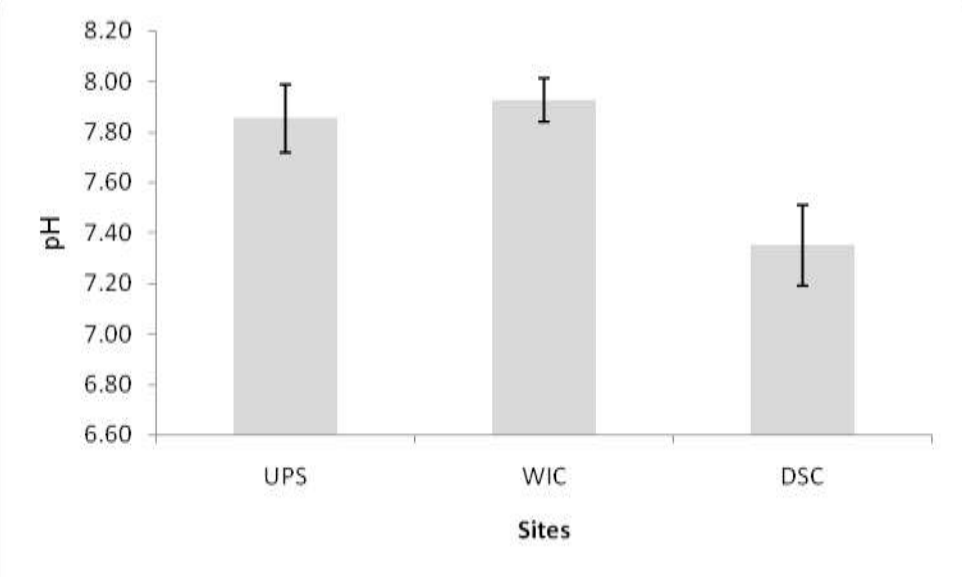

Figure. 6. Mean pH values at SON fish farm, September 2011.

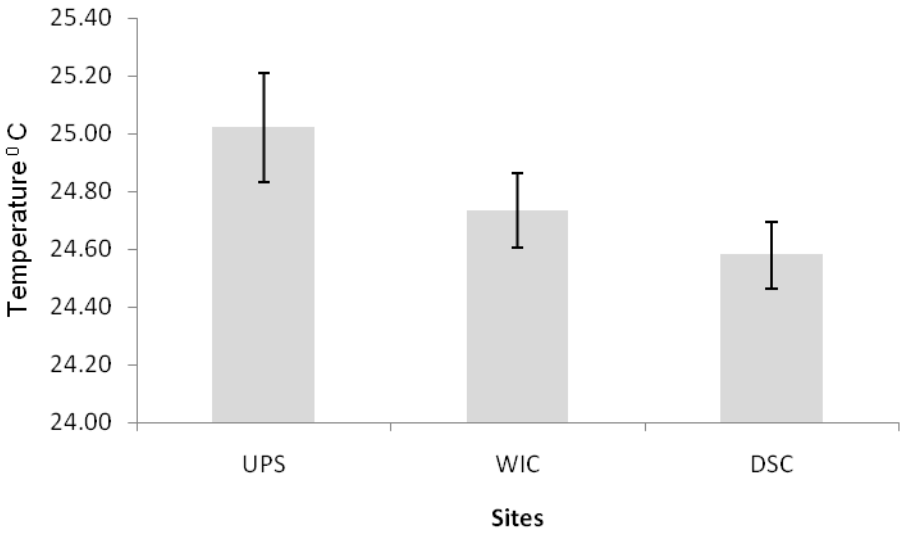

Figure.7. Mean water column temperature levels at SON fish farm, September 2011.

4.4 Nutrient status

Soluble reactive phosphorus (SRP) was highest (0.024mg/l) at the upstream site (USC) probably due to soil erosion, surface run-off from nearby agricultural lands and anthropogenic activities from fish landing site (Correll, 1999**).** When phosphorus inputs reach the water, phosphorus is released and converted to soluble inorganic phosphate the only form phytoplankton are able to assimilate (Wetzel 2001). The observed slight reduction in SRP at within the cages (WIC) site and downstream of cages (DSC) (0.022mg/l) was probably due to the dilution effect with increasing distance from the source (**Fig.8a**). Compared to the previous/May sampling, SRP levels were found to be lower probably due to the increasing dilution effects of the rains at the time of the current survey.

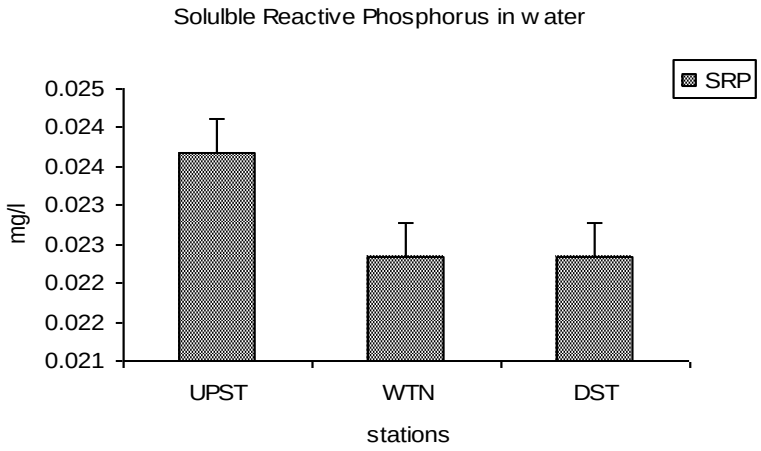

Figure. 8. a. Soluble Reactive Phosphorus at the SON fish farm, September, 2011.

Nitrite-nitrogen levels were generally low in all stations, ranging from 0.0006mg/l upstreamUSC, increasing slightly within the cages/WIC to 0.0007mg/l and downstream/DSC (0.0008mg/l probably due to the presence of fish feeds (Fig.8.b). Nitrite is released as an intermediate product during the process of nitrification and denitrification (DWAF 1996c; Bronmark & Hanson, 2005), but bacteria quickly convert nitrite (NO_2-) to other more stable nitrogen ions (Yves, 1998). High levels can be toxic to fish, animals and humans.

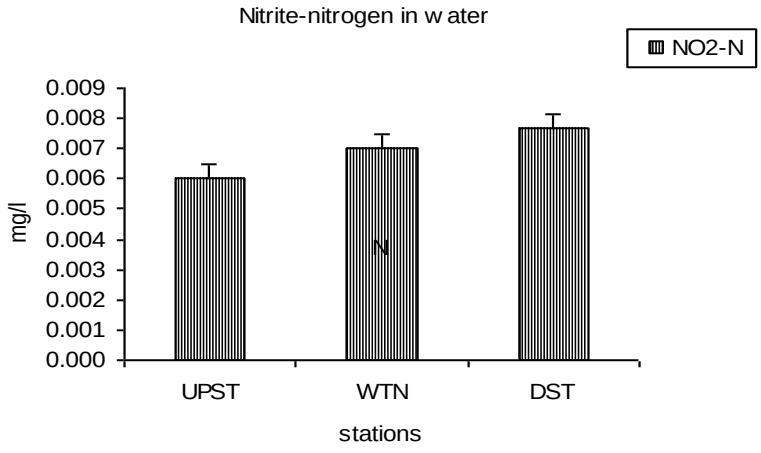

Figure 8.b. Nitrite-nitrogen at the SON fish farm, September, 2011.

Ammonia-nitrogen was slightly higher upstream/USC (0.012mg/l) in comparison to that within cages/WIC (0.009mg/l) and downstream/DSC (0.01mg/l) (Fig. 8c). This was probably due to fertilizer run-off and the decomposition of organic material such as dead aquatic plants being eroded from the catchment. The pH of 8 and temperature of 25^0 C could also have favoured the production of the non-oxidized form of ammonia (Hargreaves, 1998; Moss, 1998; Wetzel, 2001**).** The slight reduction at within the cages/WIC site may be probably due to assimilation by planktonic algae including the abundant Cyanobacteria (see Algae section above).

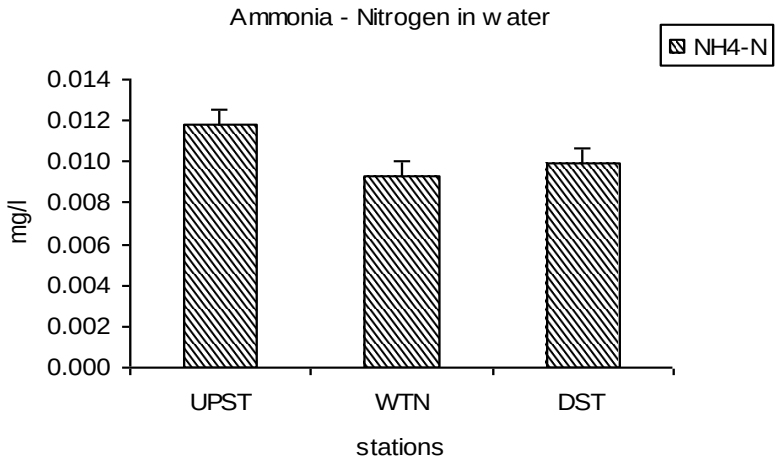

Figure 8.c. Ammonia-nitrogen at the SON fish farm, September, 2011.

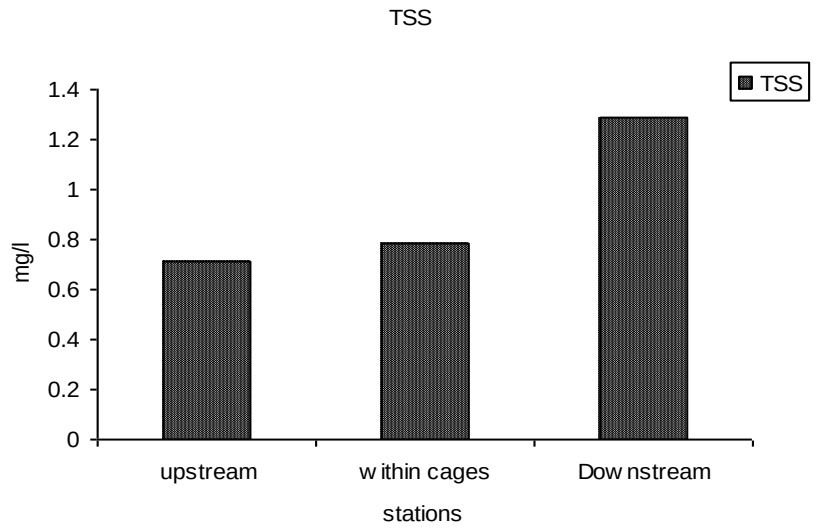

Figure 8.d. Total Suspended Solids at the SON fish farm, September, 2011.

Total suspended solids (TSS) increased from 0.71mgL^{-1} upstream/USC to 0.79mgL^{-1} within cages/WIC to 1.29mgL^{-1} downstream/DSC (Fig.8.d). This may be related to uneaten feeds and the presence of fish faecal solids in the water coupled with eroded materials from the sediment (Tlusty *et.al*. 2000).

4.5 Zooplankton community

Twenty seven (27) zooplankton species were recorded from the three study sites. Within cages (WIC) site had the lowest species number range (13 – 14) compared to

Downstream (DSC) with (12 – 18) and Upstream (USC) (14 – 18). Rotifera had more species with 5 – 8 at WIC, 6 – 10 at DSC and 6 – 9 at USC (**Table 3**).

Table 3. Zooplankton species richness and abundance ranges across sampled sites at SON fish farm, September 2011

	Species richness	**Abundance (Ind. m^{-2})**
	Numerical ranges	**Numerical ranges**
Copepoda		
Downstream of cages	5 - 6	207,284 - 311,141
Within cages	4 - 6	227,649 - 325,443
Upstream of cages	4 - 5	242,010 - 421,501
Cladocera		
Downstream of cages	1 - 2	202- 999
Within cages	2 - 2	583 - 749
Upstream of cages	3 - 4	832 - 3,079
Rotifera		
Downstream of cages	6 - 10	4,827 - 11,116
Within cages	5 - 8	4,494 - 8,322
Upstream of cages	6 - 9	6,491 - 12,316
Total		
Downstream of cages	12 - 18	213,027 - 317,632
Within cages	13 - 14	233,059 - 330,519
Upstream of cages	14 - 18	255,159 - 429,739

The highest total abundance (429,739 Ind. m^{-2}) was recorded at USC while the lowest (213,027 Ind. m^{-2}) was recorded at DSC (Table 3). Copepods contributed the highest abundances at all sites (>400,000 Ind. m^{-2}) at USC2 and USC3), followed by rotifers and cladocerans in that order (Table 1). The most dominant Copepoda species were

cyclopoid species: *Tropocyclops tenellus*, *Tropocyclops confinnis, Thermocyclops neglectus and the* calanoid *Thermodiaptomus galeboides*. Dominant Cladocera were *Ceriodaphnia cornuta*, *Moina micrura* while dominant Rofera were *Keratella tropica*, *Lecane bulla* and *Sycheata* sp. (Table 4).

Table 4. Mean (+SE) numerical abundance of zooplankton species across sites at SON fish farm, September 2011.

	DSC	**WIC**	**USC**
Copepoda			
Mesocyclops sp.	28 ± 28	- ± -	222 ± 222
Tropocyclops confinnis	5,576 ± 650	4,910 ± 1,653	2,774 ± 337
T. tenellus	2,328 ± 3,840	10,347 ± 1,453	6,214 ± 1,646
Thermocyclops emini	384 ± 26	416 ± 292	555 ± 555
T. incisus	- ± -	139 ± 139	- ± -
T. neglectus	1,296 ± 517	1,082 ± 708	2,608 ± 1,171
Thermodiaptomus galeboides	1,181 ± 145	2,136 ± 700	1,221 ± 100
Calanoid copepodites	3,000 ± 889	2,691 ± 454	3,329 ± 1,706
Cyclopoid copepodite	27,890 ± 4,654	34,559 ± 3,952	49,245 ± 12,893
Nauplii	215,979 ± 22,492	209,849 ± 34,791	244,745 ± 39,384
Cladocera			
Bosmina_longirostris	- ± -	55 ± 55	388 ± 147
Ceriodaphnia cornuta	539 ± 183	472 ± 73	610 ± 222
Diaphanosoma excisum	- ± -	- ± -	250 ± 127
Daphnia lumhortzi(helm)	- ± -	- ± -	28 ± 28
Moina micrura	166 ± 127	166 ± 127	610 ± 361
Rotifera			
Ascomorpha sp.	- ± -	55 ± 55	- ± -
Asplanchna sp.	- ± -	- ± -	55 ± 55
Brachionus angularis	444 ± 242	305 ± 169	472 ± 354
Brachionus calyciflorus	162 ± 123	- ± -	- ± -

Lacane bulla	2,718 ± 772	2,164 ± 913	2,108 ± 627
Euclanis sp.	55 ± 55	388 ± 55	250 ± 144
Filinia longiseta	55 ± 55	- ± -	277 ± 147
F. opoliensis	- ± -	55 ± 55	361 ± 361
Hexathra sp.	- ± -	55 ± 55	139 ± 139
Keratella cochlearis	555 ± 436	1,110 ± 605	666 ± 144
K. tropica	1,201 ± 443	832 ± 427	1,221 ± 341
Polyarthra vulgaris.	305 ± 154	222 ± 182	1,609 ± 182
Synchaeta pectinata	- ± -	194 ± 194	- ± -
Synchaeta sp.	1,197 ± 622	250 ± 250	888 ± 454
R_Trichocerca cylindrical	452 ± 143	194 ± 194	416 ± 416
Cercaria	28 ± 28	55 ± 28	- ± -

Generally, within cages (WC) site exhibited lower numerical abundance and species richness (Figure 9) although variation between sites did not show significant difference ($F(2,8)=0.457$; $P=0.653$). Similarly, a Post Hoc fisher's test LSD also showed no significant difference ($P>0.05$) for taxa across sites.

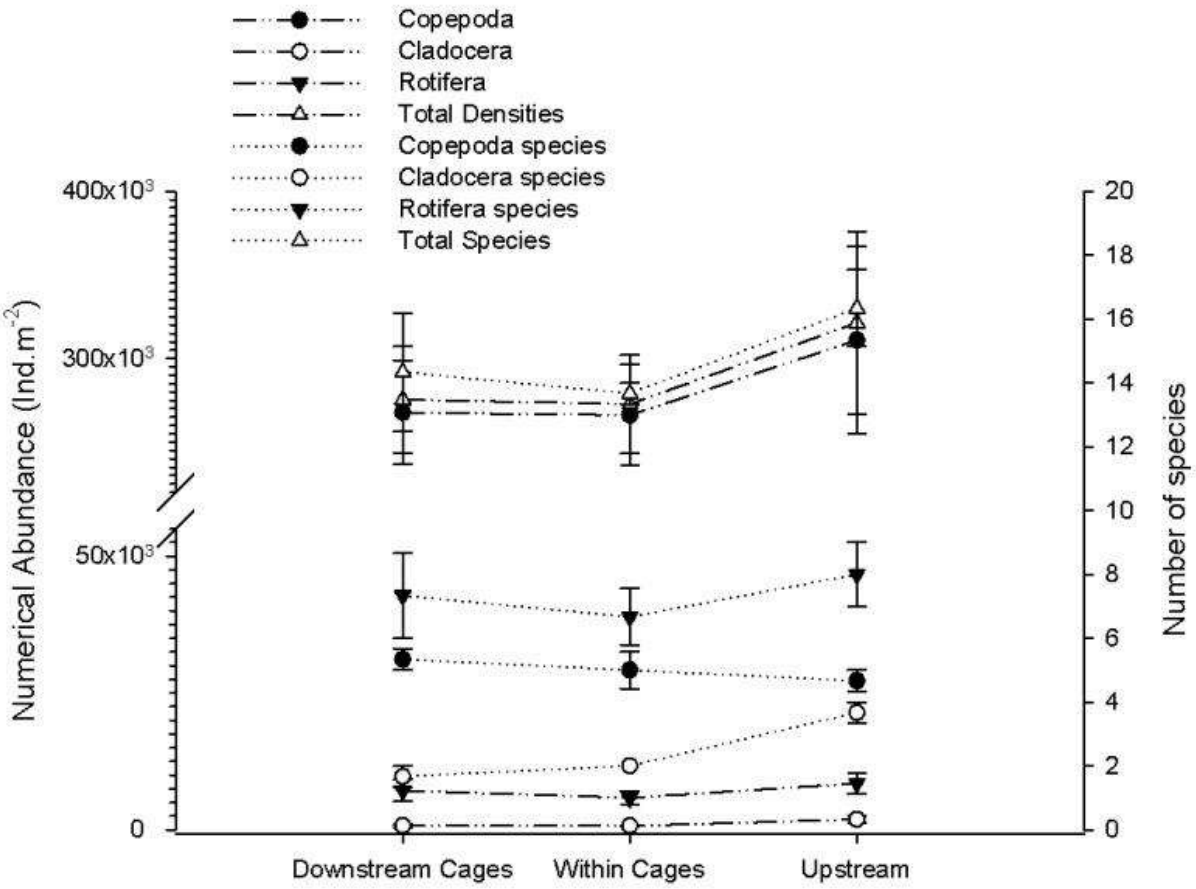

Figure 9. Mean densities) (Ind. m^{-2}(±SE) and species richness of broad zooplankton groups across sites at SON fish farm, September 2011.

4.6 Macro-benthic community

The third quarter survey registered a slight increase in the total number of macro-benthic taxa recovered (i.e. 26 up from 24 and 21 recorded in February and May respectively) from the three study sites (USC, WIC) and DSC) (**Table 5**). As in the past surveys, the community was constituted by Bilvavia and Gastropoda (Mollusca); Ephemeroptera (mayflies) Diptera (two-winged flies) and Trichoptera (caddis flies; Hirudinea (leeches) and Oligochaeta (earth worms) (**Table 5**). Two new molluscan species namely *Aspatheria sp.* (Bivalvia) and *Anisus natalensis* (Gastropoda) were found in addition to previously recorded species (i.e. *Byssanodonta prasitica* and *Corbicula africana* for Bivalvia and *Bellamya unicolor*, *Biomphalaria, Bulinus sp, Gabbia humerosa, Melanoides tuberculata* and *Lentorbis jonodi).* Dipteran larvae, maintained the highest diversity (40%) as in the previous surveys with 10 taxa. Trichoptera was represented by one taxon , *Polycentropus sp*.

Table 5. Composition/occurrence of macro-benthic taxa across sites at the SON fish farm: February, May and September 2011. (P = present).

	USC			WIC			DSC		
Taxa:	Feb.	May	Sept.	Feb.	May	Sept.	Feb.	May	Sept.
Bivalvia									
Byssanodonta parasitica	P	P		P			P		P
Corbicula africana	P		P	P	P	P		P	P
Aspatheria sp.			P			P			
Gastropoda									
Bellamyia unicolor	P	P	P	P	P	P	P	P	P
Biomphalaria sp.					P	P			
Bulinus sp.								P	P
Gabbia sp.	P			P		P	P	P	P
Melanoides tuberculata.	P	P	P	P	P	P		P	P
Anisus natalensis									P
Lentorbis junodi		P						P	
Ephemeroptera									
Caenis sp.	P	P	P			P			P
Povilla adusta	P	P					P	P	P
Leptophlebidae	P								P
Heptageniidae									P
Tricorythodes sp.							P		
Trichoptera									

Leptoceridae	P	P					P		
Polycentropus sp.	P	P	P				P	P	P
Diptera									
Ablabesmyia sp	P	P	P	P		P	P	P	P
Chironomus spp.	P			P	P	P		P	P
Clinotanypus sp.				P	P	P		P	P
Cryptochironomus sp.	P		P			P			
Procladius sp.				P					P
Tanypus sp.				P		P			P
Tarnytarsus sp.			P	P		P	P	P	P
Chironomidae	P	P	P	P			P		P
Ceratopogonidae				P	P	P			
Chaoborus sp.	P	P	P	P	P	P			
Others									
Caridina nilotica							P		
Hirudinea				P			P	P	P
Oligochaetes									
Nais sp.	P	P	P	P	P	P		P	
Total Number of taxa	16	12	12	16	9	16	12	14	20

The distribution and abundance of macro-benthos followed a comparable trend to the previous surveys in terms of total mean densities with WIC having 3137, 2087, and 3165 ind. m^{-2} for September, May and February respectively; USC with 1989, 1611, 1555 ind. m^{-2} and DSC with 1029, 560 and 1176 (Figure 10). As in previous surveys, dipterans and the gastropods were most abundant benthos particularly at WIC (mean densities of 1275 and 840 ind. m^{-2} respectively) (Figure 10).

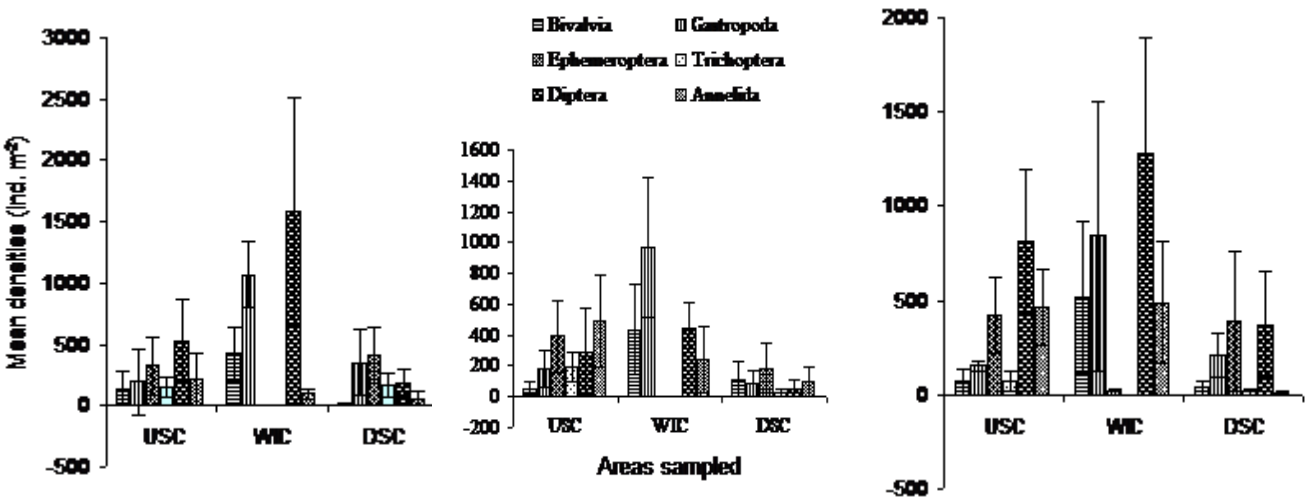

Figure 10. Composition and abundance of major macro-benthos taxa upstream cages, within cages and downstream cages ; L – R, February, May & September-2011

Bivalves were most concentrated at WIC (518 ind. m^{-2}) with 70 and 35 ind. m^{-2} at USC and DSC respectively. Ephemeropterans maintained their highest densities at USC (518 ind. m^{-2}); compared to 392 and 0 ind. m^{-2} at WIC and DSC respectively. Trichopterans exhibited reduced numbers but had comparable trends with those of the previous surveys with a mean density of 70 ind. m^{-2} at USC, 14 ind. m^{-2} at DSC and no trichopterans recovered at WIC. Nine (9) species of mollusks (*Byssanodonta parasitica, Corbicula africana, Aspatheria sp, Bellamyia unicolor, Biomphalaria sp, Bulinu sp, Gabbia humerosa, Anisus natalensis* and *Melanoides tuberculata*), were recorded. Mollusc species concentration was highest (7) at DSC and lowest (4) at USC. The most abundant species, *C. africana* (504 ind. m^{-2}) was recorded at WIC). Consistently, *M. tuberculata* dominated USC in all the three surveys with 140, 154, and 154 ind. m^{-2} September, May and February respectively (Figure 11). The gastropod species *B. unicolor*, occurred in all the three sites in all the surveys.

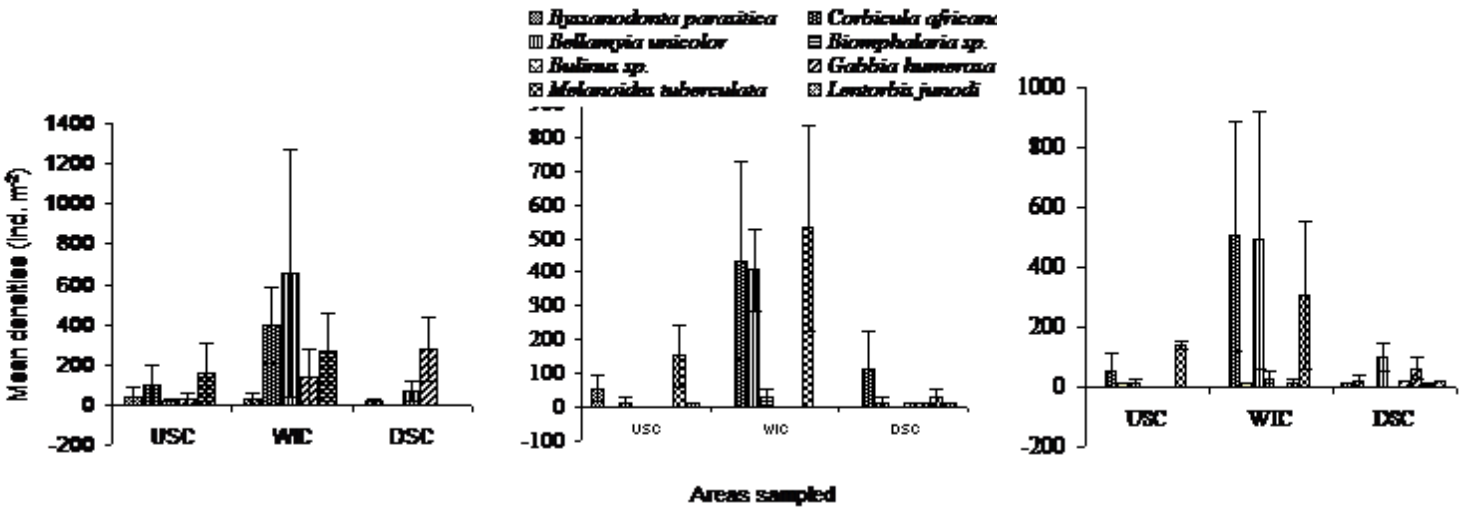

Figure 11. Composition and abundance of molluscs at the upstream of cages/USC, within cages/WIC and downstream of cages/DSC at SON fish farm: (a) February and (b) May, 2011

Two (2) EPTs, (Ephemeroptera and Trichoptera) were recorded. These were encountered at USC and DSC and none at WIC [Figure 10]. The highest density was by *Caenis sp*. (420 ind. m^{-2}) at USC, 350 and 168 ind. m^{-2} were recorded at USC in May and February respectively.

P. adusta dominated at DSC (287, 182 and 404 ind. m^{-2} respectively for the 3rd, 2nd and 1st quarters). An additional taxon, Heptageniidae was recovered.

The overall total mean densities of macro-benthos remained highest in WIC (2087 ind. m^{-2} in May and about 3100 ind. m^{-2} in both Feb. and Sept); lowest at DSC (respectively, 560, 1029 and 1176 ind. m^{-2} for May, September. and February (Figure 12).

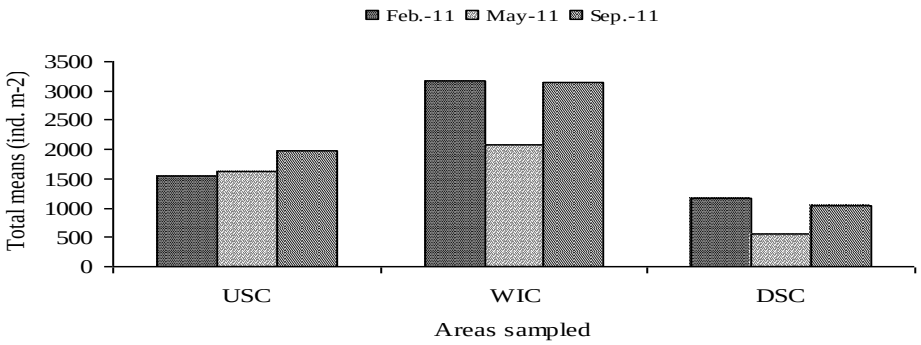

Figure 12. Total mean abundance of macro-benthos at the upstream cages/USC, within cages/WIC and downstream of cages/DSC at SON fish farm; L – R, Feb-2011 & May. 2011 and Sept. 2011

In general, the results of the third quarter survey did not differ much from these of previous ones. Slight changes occurred in the diversity and abundances but dipteran larvae remained predominant especially at the WIC site. Total number of taxa fell from 10 in February to 7 in May and then rose back to 10 in September. Their relative abundance dropped to 19% (May) from 40% (February) of the total mean density of the recorded macro-benthos. The mollusks similarly remained most concentrated at the WIC site.

As in previous surveys, the EPTs occurred only at USC and DSC and were nonexistent at WIC.

Sediment types and texture for the three sites remained similar to those described in the previous surveys.

4.7 Fish community

A total of 13 fish species 7 haplochromines (Nkejje) and 6 non-haplochromines), belonging to 4 families were recorded during the survey (Table 6). Haplochromines dominated the catch contributing 93.3% of all the fishes caught. Other fish species in order of numerical importance were *Oreochromis niloticus* (Ngege), *Lates niloticus* (Mputa), *Tilapia zilli, Clarias alluaudi (*Nsonzi*)*, Clarias gariepinus (Male) and *Mormyrus kannume* (Elephant snout fish: Kasulubana). Highest fish diversity 7species was observed at both within/WIC and downstream/DSC of cages unlike during the first quarter when highest number of fish species was recovered upstream. Fish abundance was highest within the cages (74.9%).

Table 6 . Catch rates (numbers) of fish species from SON FISH farm cages obtained during the three quarters of the survey.

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

		WIC	0	0	0				
		DSC	0	0	0				
		All	0.1	0	0				
	Synodontis victoriae	USC	0.3	0	0				
		WIC	0	0	0				
		DSC	0	0	0				
		All	0.1	0	0				
Mormyridae	*Mormyrus kannume*	USC	0.2	0.08	0.1				
		WIC	0	0	0				
		DSC	0	0	0				
		All	0.1	0.03	0.03				
Overall Rates		USC	3.3	0.5	1.2				
		WIC	2.3	0.9	19.1				
		DSC	6.5	4.5	5.2				
		All	4	2	8.5				
No of species recovered		USC	12	5	4				
		WIC	5	4	5				
		DSC	8	8	3				
		All	16	11	7				

4.7.1 The haplochromines

Seven (7) species belonging to 5 genera of haplochromines were encountered during the survey (Table 7). Highest fish species diversity (5 species) was recorded downstream/DSC although the largest amount of fish (95%) were from within the cages/WIC. The most abundant haplochromines still belonged to the genus *Astatotilapia* (74.3%) followed by *Paralabidochromis* (16%) and *Mbipia* (1.8%). 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.

Table 7. Percent contribution (by numbers) of haplochromine species from SON fish cages obtained during the three survey periods.

Sampling period			Q1	Q2	Q3	Q4
Date of sampling			Feb. 2011	May. 2011	Sep. 2011	
Season			Dry	Wet	Wet	
Genus	**Species**	**Site**				
Astatoreochromis	*A.alluaudi*	USC	0	0	0	
		WIC	0	0	0	
		DSC	1.5	0	0.6	
		All sites	1.5	0	0.6	
Astatotilapia	*A. "thick lip"*	USC	3.6	0	0	
		WIC		0	0	
		DSC		0	0	
		All sites	3.6	0	0	
	A. "pink anal"	USC		0	0	
		WIC		0	0	
		DSC		60.3	0	
		All sites		60.3	0	
	Astatotilapia sp	USC	12.3	0	0.9	
		WIC	6.5	8.6	68.3	
		DSC	42.3	15.5	5.1	
		All sites	60.9	24.1	74.3	
Lipochromis	*L. parvidens*	USC	0.7	0	0	
		WIC	0	0	0	
		DSC	0	1.7	0	
		All sites	0.7	1.7	0	
Lithochromis	*Lithochromis sp*	USC	0	0	0	
		WIC	0	1.7	0	
		DSC	0	0	0	
		All sites	0	1.7	0	
Mbipia	*M."blue"*	USC	0.7	0	0	
		WIC	0	0	0	
		DSC	0	0	0	
		All sites	0.7	0	0	
	M. mbipi	USC	0	0	1.8	
		WIC	0	0	0	
		DSC	0	0	0	

		All sites	0	0	1.8	
Paralabidochromis	*P. "blackpara"*	USC	1.5	3.4	0	
		WIC	0.7	0	2.1	
		DSC	8.7	3.4	13.6	
		All sites	10.9	6.9	15.7	
	P. victoriae	USC	0	0	0	
		WIC	0	0	0.3	
		DSC	0	0	0	
		All sites	0	0	0.3	
Psammochromis	*P. riponianus*	USC	0	1.7	0	
		WIC	2.2	0	0	
		DSC	4.4	0	0.3	
		All sites	6.5	1.7	0.3	
Pyochromis	*Ptyochromis sp*	USC	0	0	0	
		WIC	0	0	0	
		DSC	2.2	0	0	
		All sites	2.2	0	0	
Pundamilia	*Pundamilia sp*	USC	0.7	0	0	
		WIC	10.9	0	0	
		DSC	0	0	0	
		All sites	11.6	0	0	
	P. macrocephala	USC	1.5	0	0	
		WIC	0	0	0	
		DSC	0	0	0	
		All sites	1.5	0	0	
Xystichromis	*X. "earthquake"*	USC	0	0	0	
		WIC	0	0	0	
		DSC	0	3.4	0	
		All sites	0	3.4	0	
	X. phytophagus	USC	0	0	0	
		WIC	0	0	0	
		DSC	0	0	0.3	
		All sites	0	0	0.3	
Overall Contribution		USC	21	5.2	4.5	
		WIC	20.3	10.3	74.9	
		DSC	58.7	84.5	20.5	
		All sites	100	100	100	

No of species recovered		USC	7	2	2	
		WIC	4	2	3	
		DSC	5	5	5	
		All sites	10	7	7	

4.7.2 Fish 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 numbers, catch rates were highest within the cages (19.5) (Table 7) while by weight rates were highest upstream (302g per net) (Table 8). Haplochromines recorded the highest rates (25.8 and 300g by numbers and weight respectively).

Overall mean rates during the period under review (September 2011) were calculated at 8.5fish and 226g per net by numbers and weight respectively (Table 8).

Table 8. Fish Catch rates by weight (g) of fish caught in SON fish farm (Q2, Q1 & Q3) 2011.

Sampling period			**Q1**	**Q2**	**Q3**	**Q4**			
Date of sampling			Feb. 2011	May. 2011	Sep. 2011				
Season			Dry	Wet	Wet				
Family	Species	Site							
Centropomidae	*Lates niloticus*	USC	118.9	1.38	138				
		WIC	17.8	126.3	1				
		DSC	3.7	8.0	0				
		All	46.8	45.2	46				
Characidae	*Brycinus jacksoni*	USC	0	0	0				
		WIC	0	0	0				
		DSC	0	34.5	0				
		All	0	11.5	0				
Cichlidae	Haplochromines	USC	96.5	19.0	35				
		WIC	70	10.5	520				
		DSC	411	243.5	345				
		All	192.5	91.0	300				

	Oreochromis niloticus	USC	0	5.2	0				
		WIC	0	9.9	79				
		DSC	0.9	0.5	16				
		All	0.3	5.2	32				
	Tilapia zillii	USC	38.3	0	0				
		WIC	0	0	3				
		DSC	2.3	0	12				
		All	13.5	0	5				
Clariidae	*Clarias alluaudi*	USC	0	0	0				
		WIC	0	0	17				
		DSC	0	0	0				
		All	0	0	6				
	Clarias gariepinus	USC	0	0	147				
		WIC	0	0	0				
		DSC	0	0	0				
		All	0	0	49				
Mochokidae	*Synodontis afrofischeri*	USC	5	0	0				
		WIC	0	0	0				
		DSC	0	0	0				
		All	1.7	0	0				
	Synodontis victoriae	USC	21.5	0	0				
		WIC	0	0	0				
		DSC	0	0	0				
		All	7.2	0	0				
Mormyridae	*Mormyrus kannume*	USC	32.3	61.1	6				
		WIC	0	0	0				
		DSC	0	0	0				
		All	10.8	20.4	2				
Overall Rates		USC	212.6	73.5	302				
		WIC	39.4	139.4	246				
		DSC	132.5	94.0	129				
		All	128.2	102.3	226				
No of species recovered		USC	12	5	4				
		WIC	5	4	5				
		DSC	8	8	3				
		All	16	11	7				

Table 9. Percent contribution (by numbers) of haplochromine species obtained in SON fish farm (Q2, Q1 & Q3) 2011.

Sampling period			Q1	Q2	Q3	Q4
Date of sampling			Feb. 2011	May. 2011	Sep. 2011	
Season			Dry	Wet	Wet	
Genus	**Species**	**Site**				
Astatoreochromis	*A.alluaudi*	USC	0	0	0	
		WIC	0	0	0	
		DSC	1.5	0	0.6	
		All sites	1.5	0	0.6	
Astatotilapia	*A. "thick lip"*	USC	3.6	0	0	
		WIC		0	0	
		DSC		0	0	
		All sites	3.6	0	0	
	A. "pink anal"	USC		0	0	
		WIC		0	0	
		DSC		60.3	0	
		All sites		60.3	0	
	Astatotilapia sp	USC	12.3	0	0.9	
		WIC	6.5	8.6	68.3	
		DSC	42.3	15.5	5.1	
		All sites	60.9	24.1	74.3	
Lipochromis	*L. parvidens*	USC	0.7	0	0	
		WIC	0	0	0	
		DSC	0	1.7	0	
		All sites	0.7	1.7	0	
Lithochromis	*Lithochromis sp*	USC	0	0	0	
		WIC	0	1.7	0	
		DSC	0	0	0	
		All sites	0	1.7	0	
Mbipia	*M."blue"*	USC	0.7	0	0	
		WIC	0	0	0	
		DSC	0	0	0	
		All sites	0.7	0	0	
	M. mbipi	USC	0	0	1.8	
		WIC	0	0	0	

		DSC	0	0	0	
		All sites	0	0	1.8	
Paralabidochromis	*P. "blackpara"*	USC	1.5	3.4	0	
		WIC	0.7	0	2.1	
		DSC	8.7	3.4	13.6	
		All sites	10.9	6.9	15.7	
	P. victoriae	USC	0	0	0	
		WIC	0	0	0.3	
		DSC	0	0	0	
		All sites	0	0	0.3	
Psammochromis	*P. riponianus*	USC	0	1.7	0	
		WIC	2.2	0	0	
		DSC	4.4	0	0.3	
		All sites	6.5	1.7	0.3	
Pyochromis	*Ptyochromis sp*	USC	0	0	0	
		WIC	0	0	0	
		DSC	2.2	0	0	
		All sites	2.2	0	0	
Pundamilia	*Pundamilia sp*	USC	0.7	0	0	
		WIC	10.9	0	0	
		DSC	0	0	0	
		All sites	11.6	0	0	
	P. macrocephala	USC	1.5	0	0	
		WIC	0	0	0	
		DSC	0	0	0	
		All sites	1.5	0	0	
Xystichromis	*X. "earthquake"*	USC	0	0	0	
		WIC	0	0	0	
		DSC	0	3.4	0	
		All sites	0	3.4	0	
	X. phytophagus	USC	0	0	0	
		WIC	0	0	0	
		DSC	0	0	0.3	
		All sites	0	0	0.3	
Overall Contribution		USC	21	5.2	4.5	
		WIC	20.3	10.3	74.9	
		DSC	58.7	84.5	20.5	
		All sites	100	100	100	
No of species		USC	7	2	2	

recovered						
		WIC	4	2	3	
		DSC	5	5	5	
		All sites	10	7	7	

4.7.3 Biology of common fish species

The biology of common fish species caught from the cage area in all quarters sampled in 2011 is summarized in Table10. Other than haplochromines the rest of fish species were in such low numbers that not much information can be inferred from the data.

Table 10. Basic biological parameters of fish species caught SON Fish site February, May and September 2011.

Sampling period	Parameter	Q1	Q2	Q3	Q4
Date of sampling		Feb. 2011	May. 2011	Sep. 2011	
Season		Dry	Wet	Wet	
Species					
Clarias alluaudi	Size range (cm)	0	0	13.6 – 15.1	
	% mature	0	0	100	
	Number examined	0	0	3	
Clarias gariepinus	Size range (cm)	0	0	61	
	% mature	0	0	Mature	
	Number examined	0	0	1	
Lates niloticus	Size range (cm)	10 - 45	9 - 36	9 - 51	
	% mature	All immature	All immature	20	
	Number examined	9	9	5	
Brycinus jacksoni	Size range (cm)	0	13 - 15	0	
	% mature	0	All mature	0	
	Number examined	0	3	0	
Haplochromines	Size range (cm)	7.0 – 12.4	7.4 – 12.5	6.7 – 13.6	

	% mature	98	74	60	
	No examined	59	43	48	
Tilapia zillii	Size range (cm)	9 - 20	0	7 – 17	
	% mature	75	0	25	
	No examined	4	0	4	
Mormyrus kannume	Size range (cm)	20 - 29	42	20	
	% mature	33	100	immature	
	No examined	3	1	1	
Oreochromis niloticus	Size range (cm)	9	7 - 17	7 - 28	
	% mature	Immature	All immature	All immature	
	No examined	1	4	8	
Synodontis afrofischeri	Size range (cm)	10	0	0	
	% Mature	mature	0	0	
	No examined	1	0	0	
Synodontis victoriae	Size range (cm)	18	0	0	
	% mature	Mature	0	0	
	No examined	1	0	0	

Fish catch rates were higher than those calculated during the previous surveys. Increase in numbers was largely due to the very many haplochromines caught especially in the fleet within cages. This fleet had been dragged to the shoreline where haplochromines abound by people beach seining in the area. The weight was contributed by a large Nile perch, and *Clarias* and two large farmed tilapias that probably escaped from the cages and were caught in the nets. Catches from within the cages/WIC contributed the lowest figures.

While it may be too early to explain fish distribution at the sites sampled, it is worthwhile noting that there was more fish downstream/DSC and that the fleet set within the cages/WIC yielded least amount of 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 attracts fish in this area.

In summary, 13 fish species (7 (7, 10) haplochromines and 6 (4, 6) non-haplochromines), belonging to 4 families were recorded in the vicinity of the cages; both fish species diversity and catch rates were highest downstream/DSC. Just like in the previous survey, least fish was caught within the cage/WIC area. Generally, fish catch rates were higher than those calculated for the previous survey. The diet of fishes encountered consisted of known natural foods of the species caught. Remnants of food fed to the cage fish were not recovered in the stomachs of the wild fishes. However stomachs of the two tilapias that presumably escaped from the cages and were caught in our nets contained fish feed supplied by SON Fish. No serious infection by fish parasites was noticed on the fishes caught. A few common nematodes were occasionally encountered in the guts of some haplochromines.

5.0 General conclusion

Current observations from physical-chemical parameters, nutrient status, invertebrate and fish communities indicate that the water quality at the fish cage site is still good in terms of aquatic ecosystem health. However, as more and more cage units are added, the environment status/quality and biological productivity may be compromised as widely reported elsewhere. The September observations showing low fish species diversity, higher concentration of stress-tolerant organisms (i.e. dipteran larvae and molluscs), absence of pollutant-sensitive macro-benthos (EPTs), low zooplankton abundance and species richness, high algal biomass of blue-green algae and chlorophyll a levels at the within cages/WIC site are signs of developing stressful conditions, which could in future result in undesirable impacts in water quality and aquatic communities. The present observations probably indicate the likely effects of the cage density in the area and the feeding regimes. There is therefore need to maintain regular environmental monitoring surveys at the site on order to keep track of any negative developments that may be associated with the fish cages facility.

6.0 References

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