ENVIRONMENTAL CONDITIONS AND NATURAL FOOD RESOURCES FOR COMMERCIAL FISH PRODUCTION IN THE VALLEY DAMS OF MBARARA DISTRICT, UGANDA

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Abstract

The Mabira, Kyenshama and Rushozi valley dam reservoirs in the Mbarara District, Uganda, provide suitable environmental conditions for fishery exploitation and controlled fish farming and/or ranching management. Physico-chemical parameters were correlated to primary production in Rushozi and Kyenshama and to altitude and geology in Mabira. All dams were eutrophic with nitrogen likely to be limiting in Mabira and Rushozi and phosphorus in Kyenshama. Phytoplankton abundance (with Chlorophyceae and Cyanobacteria dominance) was significantly higher in Rushozi ($p < 0.05$). Abundance of zooplankton and benthic macroinvertebrates was similar across dams. Nile tilapia (Oreochromis niloticus) and African catfish (Clarias gariepinus) were the dominant and available culture species. Their condition based on length and weight correlation was highest in Rushozi dam (1.86 ± 0.18 and 0.63 ± 0.07 for tilapia and catfish, respectively) and coincided with the highest oxygen, temperature, food uptake and phytoplankton abundance and biomass (according to chlorophyll-a concentration). Detritus, plant material, and phytoplankton were the most important diet items for both tilapia and catfish however the level of justifiable food coincidence (~ competition) was very low amounting to 2.9% in phytoplankton. The majority of food coincidence concerned low valued food items – detritus (12.7%) and plant material (14.7%).

Key words: valley dam reservoir, environment, phytoplankton, zooplankton, zoobenthos, Nile tilapia, African catfish, Mbarara district

INTRODUCTION

In Uganda fish production from natural water bodies was one of the major foreign exchange earners until 2008. Currently the natural stocks are dwindling yet local and foreign fish demand deficits have been projected to a tune of 160 000 tonnes by the year 2015. To supplement and reduce pressure on wild fish stocks from surging demand, development of aquaculture were undertaken in ponds. However, substantial increase in energy and food prices since 2007 as well as the threat of climate change, reveal changing conditions for fisheries and aquaculture (FAO, 2008).

In Uganda's semi-arid cattle corridor, over 425 valley dams/tanks had been built by the year 2003 (Kamal et al., 2003) to boost water for production, one of the seven pillars of the Plan for the Modernization of Agriculture (PMA) through irrigation and water harvesting to sustain household and livestock feed drinking water. This was to take advantage of a large water volume held thus the long time taken to dry up with prolonged drought. Mbarara is one of the cattle corridor districts with over 50 of such dams (Tibihika, 2004).

As a pilot, this study was aimed to provide baseline information on a suite of physico-chemical parameters, food organisms, body condition and food habits of existing two culture fish species (Nile tilapia, *Oreochromis niloticus* and African catfish, *Clarias gariepinus*) in three selected dams as a support tool for strategic integration of fish production and water quality improvement. The output of the study is supposed to suggest realistic water quality management strategies that may be useful for sustainable and increased fish production in the multipurpose valley dams.

MATERIALS AND METHODS

Study area

The Mbarara district lies in Western Uganda at an altitude of around 1300–1400 m (0º20.5'S 30°31'E). The vegetation is characterized by short savannah grasslands and a bimodal climate with two rainy seasons – short from February to May and long from August to December, separated by two dry spells; the long one from June

Tab. 1: Background about study dams

Dam reservoir	Mabira	Kyenshama	Rushozi
Immediate land use	pasture & banana	road, pasture & trading centre	pasture & road
Altitude (m)	1440	1360	1380
Valley shape	V	U	flat U
Free surface area (ha)	35	15	30
Mean depth (m)	3.2	4	2.6
Shoreline vegetation coverage (%)	45%	95%	10%
Shoreline vegetation type	*Cyperus papyrus*	*Typha*, *Persicaria*	local grass land vegetation
Submerged macrophytes	no	*Ceratophyllum* sp.	no
Fishing effort (no of canoes)	1	1	1

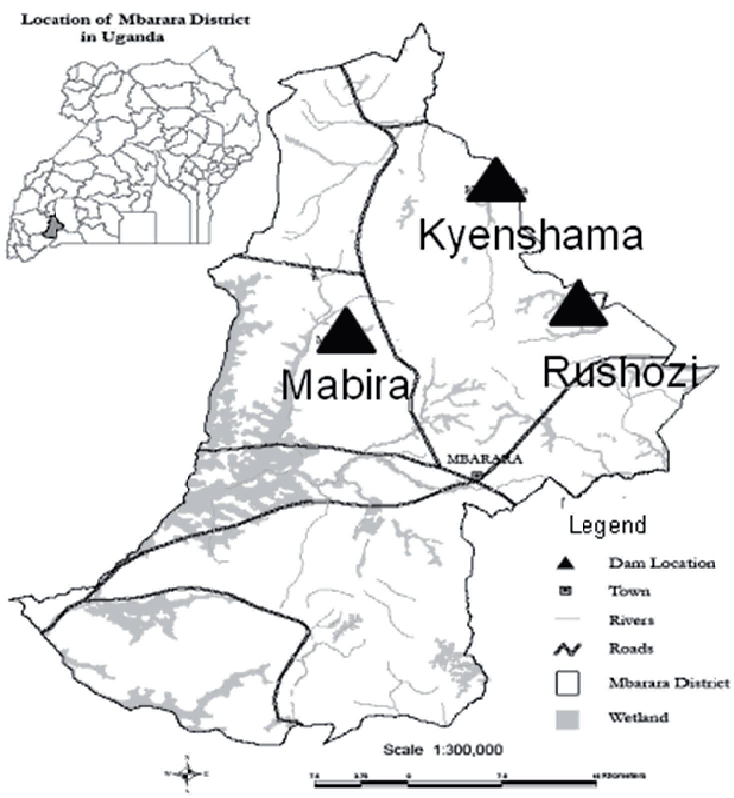
to August and a short between January and February. Temperatures range from 15ºC to 35ºC most of the year. The average rainfall is estimated at 120cm per annum (NEMA, 1997). The soils are mainly sandy and clay loams.

Three dam reservoirs, Mabira, Kyenshama and Rushozi, were studied out of seven functional ones from a total of 22 under siltation threat. Dam selection was based on size, accessibility and macrophyte coverage (Table 1). Their location within the district is shown on Figure 1.

Sampling design

Sampling was done in two events on each of the dam reservoirs in November–December 2009. Two sites were designated at the deepest side (also called dam) and shallow part (upper) in each reservoir from where integrated samples were taken. Water samples were collected with a 2-litre Patalas water sampler and filtered into one litre plastic bottles for dissolved nutrients analysis. Unfiltered samples for total nutrients, TSS, alkalinity & turbidity

Figure 1: Map of Mbarara district showing the location of dams



were collected into one litre plastic bottles. Unfiltered BOD and COD samples were collected into Duran glass bottles and acid–washed glass bottles, respectively. A total of 10 replicate samples was collected for orthophosphate, total phosphorus, nitrate-nitrogen, total nitrogen, TSS, total alkalinity, BOD and COD. All water samples were cooled immediately with ice cubes in cool boxes and later kept in refrigerator at 4°C to avoid freezing before analysis. The lab based analysis was done according to standard methods (APHA, 1995). Water depth, temperature, pH, dissolved oxygen, Secchi depth transparency and conductivity were determined on site.

Phytoplankton samples were obtained by scooping 25 ml of water sample within the surface layer without concentration. The samples were immediately fixed with 10% Lugol's iodine solution. For chlorophyll-*a* concentration, known volumes of integrated water samples were filtered through Whatman (UK) FG/C 47 mm (0.45 µm) micro glass fibre filters secured by Swinnex filter holders aided by a hand pump (MiTYvAC type). Filters were folded, wrapped in aluminium foil into tightly closed vials. Chl-*a* samples were cooled immediately and later kept in refrigerator at 4°C. Phytoplankton samples were examined for species density and composition using a Sedgwick-Rafter counting chamber on a binocular at 400 magnifications according to keys by Belcher and Swale (1976) and Dillard (1999). Chl-*a* was extracted from samples with absolute acetone in the refrigerator at 10°C for 16 hours. Pigment intensity was determined in a spectrophotometer at 665 and 750 nm with acetone as a reference (blank) following Holm-Hansen and Riemann (1978) procedure.

Zooplankton was got with 80 µm conical net (21 cm diameter & 47.5 cm height) vertically hauled through a known distance (depth). Zooplankton samples were preserved in 4% formaldehyde. One ml of homogenized zooplankton sample was fully counted and identified on a Sedgwick-Rafter counting chamber under a binocular microscope at 200 magnifications. Identification was according to Fernando (2002).

Bottom samples for benthic macroinvertebrates were collected with a Petersen's mud grab (25 × 25 cm), washed through 700 µm sieve net into 2 litre buckets and preserved in 4% formaldehyde. In the laboratory, the samples were carefully washed and macrozoobenthos was picked out and preserved in 70% ethanol for counting. For benthic macroinvertebrates, total counts were made with identification into two only occurring families of water larvae of dipteran, namely midge flies (Chironomidae) and phantom midges (Chaoboridae).

Fish samples were collected from open water with a 30 m beach seine net (25 mm mesh size, 2 m deep) hauled in 3 different sites in an area of approximately 1000 m^2 each. Gillnets (76 mm, 10 m long and 2 m deep) and 100-hook (size 8) long line were also set in the littoral zones to diversify the spectrum of fish species recorded but did not yield substantial numbers. Fish numbers and biomass were recorded on site. Being major aquaculture species, 115 Nile tilapia and 13 African catfish were selected for examination and analysis. With a measuring board, total length (TL) and standard length (SL) were measured to the nearest 1 mm and weight by an electronic balance to the nearest 0.1 g. Identification was according to Greenwood (1966) and Okaronon et al. (1997). Fish condition was presented as Fulton's coefficient (K) modified by Johnstone (1912).

Individually packed fish stomachs were preserved with 4% formaldehyde for further processing. In the laboratory, they were blotted dry, weighed before and after emptying contents into a Petri dish to get content weight. The contents were observed under a dissecting microscope at 400 magnifications to indentify major categories and food organisms. The diet was analyzed using a combination of indices including index of stomach fullness, frequency of occurrence, weight percentages, preponderance and Costello's (1990) model as amended by Amundsen et al. (1996) to avoid result distortion. The diet was expressed as weight percentage (% W_i), frequency of occurrence (% F_1), and the indices of stomach fullness (IF in $^{o}/_{ooo}$) and preponderance (Natarajan and Jhingran, 1961). Food selectivity coefficient was evaluated according to Jacobs (1974). Food coincidence indicating the level of competition was assessed according to Shorygin (1954).

Statistical analysis

Statistics was performed using Statistica programme version 9.0. Kruskal–Wallis H-test for one way analysis of variance on ranked means was used to compare abundance of food organisms in the water (plankton and macroinvertebrates), fish condition coefficitents and amount of food consumed between the dam reservoirs. Significant differences were analyzed by the multiple pair-wise comparisons on ranked means (MCRM) to determine which characteristics differed whenever required. The 0.05 probability (95% confidence limit) was used to declare differences. Dam correlations with physico-chemical factors were detected with multivariate statistics based on the principle component analysis (PCA).

RESULTS

Physico-chemical characteristics

The results of the assessment of main physico-chemical determinants from the three dam reservoirs under study are

Tab. 2: Major physico-chemical determinants from the three dam reservoirs under study

Characteristics	Unit	Mabira	Kyenshama	Rushozi
Depth	m	3.18 ± 0.66	3.91 ± 2.48	2.50 ± 0.64
SRP	$mg.l^{-1}$	0.03 ± 0.05	0.2 ± 0.11	0.16 ± 0.11
Total phosphorus	$mg.l^{-1}$	0.11 ± 0.11	0.25 ± 0.12	0.23 ± 0.05
NO_3-N	$mg.l^{-1}$	0.06 ± 0.11	0.02 ± 0.03	0.03 ± 0.31
Total nitrogen	$mg.l^{-1}$	1.10 ± 0.43	0.47 ± 1.10	2.47 ± 2.0
Alkalinity	$mg.l^{-1}$	103.7 ± 23.9	42.9 ± 4.01	63.8 ± 22.18
Conductivity	$mS.m^{-1}$	63.65 ± 0.49	11.57 ± 0.95	16.06 ± 0.19
pH		8.03 ± 0.29	7.12 ± 0.39	8.09 ± 0.43
Turbidity	NTU	10.77 ± 0.53	6.12 ± 1.32	14.13 ± 2.64
O_2	$mg.l^{-1}$	7.0 ± 1.90	1.36 ± 1.224	8.10 ± 3.92
Oxygen saturation	%	70.0 ± 23.95	13.69 ± 12.93	99.0 ± 48.66
Temperature	°C	22.58 ± 0.41	23.29 ± 1.17	24.34 ±0.73
Secchi depth	m	0.45 ± 0.07	0.53 ± 0.81	0.23 ± 0.03
Chl-*a*	$\mu g.l^{-1}$	89 ± 40.70	98.32 ± 11.87	220.06 ± 20.35
BOD_5	$mg.l^{-1}$	3.4 ± 1.02	3.5 ± 0.81	3.7 ± 1.29
COD_{Mn}	$mg.l^{-1}$	54 ± 32.67	79.83 ± 88.04	103.67 ± 80.49
TSS (105°C)	$mg.l^{-1}$	15.0	16.0 ± 2.83	24.0 ± 2.83
TSS (500°C)	$mg.l^{-1}$	4.50 ± 0.71	5.50 ± 0.71	2.5 ± 0.71

presented in Table 2. As presented by PCA (Figure 2 and 3), the Rushozi and Kyenshama reservoirs were important on the first axis (x) but opposite ends correlated with turbidity, oxygen, BOD, pH and Secchi depth. The Mabira dam reservoir was important on the second axis (y) correlated to COD, alkalinity, temperature and nutrients.

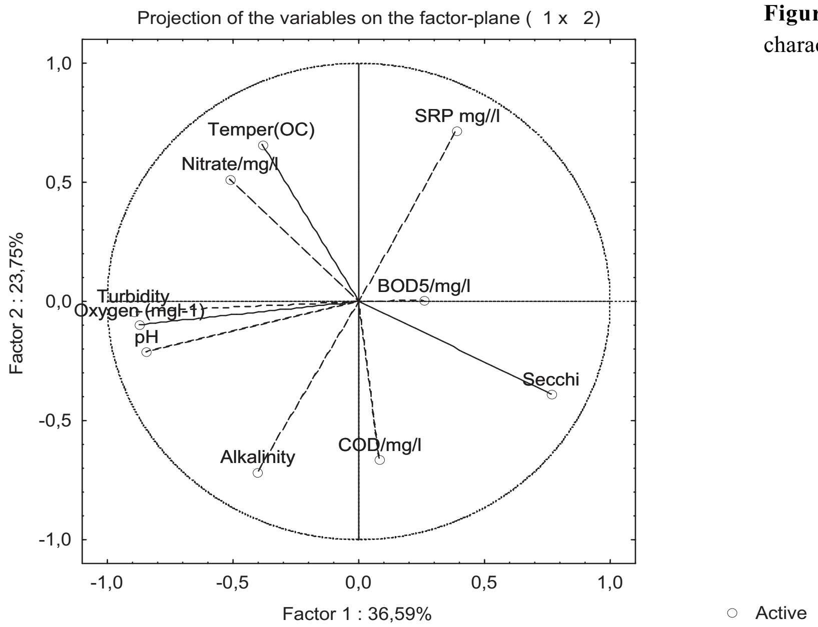
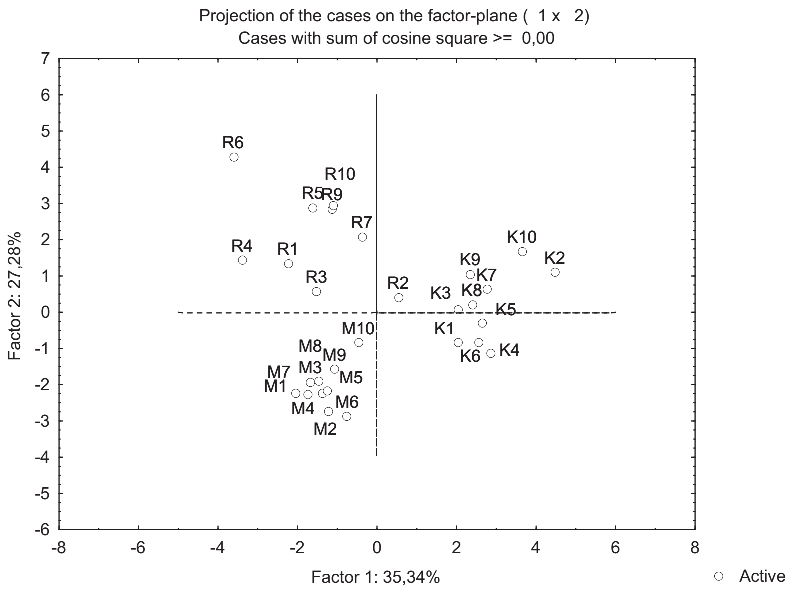


Figure 2: Selected physico-chemical characteristics projected on factor plane

Figure 3: Samples projected onto the selected physico-chemical factor plane



Note: M = Mabira, K = Kyenshama, R = Rushozi, Nos. 1–10 = factor replicates

The ratio of total nitrogen to total phosphorus as a measure of nutrient balance was higher in both Mabira and Rushozi than in Kyenshama. Organic matter was highest in Rushozi and carbonate alkalinity (buffer capacity) highest in Mabira (Table 3).

Phytoplankton

Phytoplankton abundance (cells.ml^{-1}) and distribution are presented in Table 4. Overall phytoplankton density differed among the dams (K-W test, $p < 0.05$), due to significantly higher algal density in Rushozi than in Kyenshama (MCMR, $p < 0.05$). Rushozi had the highest abundance 1.24×10^5 > Mabira 6.93×10^4 > Kyenshama 3.55×10^4 cells.ml^{-1} and chlorophyll *a* concentrations 220 > Mabira 98.3 > Kyenshama 89 µg.l^{-1}.

Phytoplankton assemblage was dominated by Cyanobacteria (especially *Microcystis* and *Anabaena*) prevailing over Chlorophyceae (majorly *Ankistrodesmus, Nephrocytium limnetica* and *Scenedesmus*) and other algal taxa.

Zooplankton

Overall zooplankton density did not significantly differ between the dams (K-W test, $p > 0.05$). Total zooplankton density was 2201, 1301 and 929 ind.l^{-1} in Rushozi, Ma-

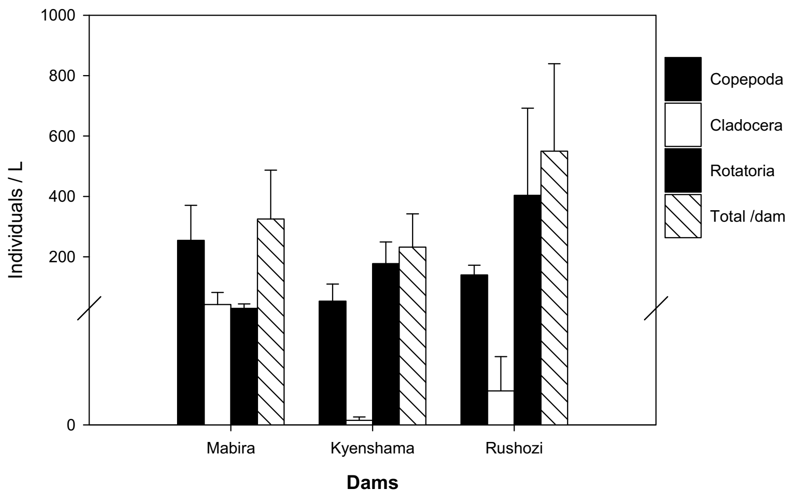
Tab. 3: Derived parameters (from TP & TN, TSS at 105 and 500ºC and conductivity & total alkalinity, respectively)

Dam	TN : TP ratio	Organic TSS (mg.l^{-1})	Carbonate alkalinity (mg.l^{-1})
Mabira	10	10.5 ± 0.7	582.3 ± 3.2
Kyenshama	1.9	10.5 ± 3.5	74.0 ±8.1
Rushozi	10.7	21.5 ± 2.1	95.0 ±2.8

Tab. 4: Phytoplankton abundance (cells.ml^{-1}) and distribution

Dams	Cyanobacteria	Bacillariophyceae	Chlorophyceae	Euglenophyceae	Total
Mabira	30 750	2 750	32 750	3 000	69 250
Kyenshama	11 750	3 250	18 000	2 500	35 500
Rushozi	62 500	5 000	56 750	250	124 500

Figure 4: Abundance and composition of zooplankton



bira and Kyenshama, respectively. Categorically the density of copepods did not also differ among dams (K-W test, $p > 0.05$) although they were comparably higher in Mabira than in Rushozi and Kyenshama (255, 145 and 54 ind.l^{-1}, respectively). The density of cladocerans and rotifers differed among dams (K-W test, $p < 0.05$). Cladocerans had significantly higher density in Mabira than in Kyenshama (MCMR, $p < 0.05$) while the density of rotifers was significantly lower in Mabira than in Rushozi (MCMR, $p < 0.05$). Cladocerans were dominated by *Ceriodaphnia*, copepods by *Cyclops* (in copepodite and nauplii stages) and rotifers by *Brachionus* (Figure 4).

Macrozoobenthos

There was no significant difference in the density among the dams (K-W test, $p > 0.05$). Only midges of Chironomidae and Chaoboridae families were found (Table 5). However, the abundance of the two families differed (K-W tests, both $p < 0.05$) due to significantly lower density of Chaoboridae (56.6 ind.m^{-2}) in Kyenshama than Rushozi (113.2 ind.m^{-2}), (MCMR, $p < 0.05$) and chironomid absence in the same dam compared to Mabira with 532.5 ind.m^{-2} (MCMR, $p < 0.05$).

Fish

Biomass, species composition and condition

Altogether, 4588 fish were caught. The mean CPUE of the seine net in 100 m^2 area corresponded to 510 fish per haul and was highest in Mabira 533 > Kyenshama 524 > Rushozi 473 individuals. The highest biomass was estimated in Kyenshama (916 kg.ha^{-1}), followed by Rushozi (321 kg.ha^{-1}) and Mabira (128 kg.ha^{-1}).

Nile tilapia was the most numerous fish species in all three dam reservoirs under study (Table 6). They attained an average weight of 39.4, 77.2 and 54.9 g in Mabira, Kyenshama and Rushozi dams, respectively. TL

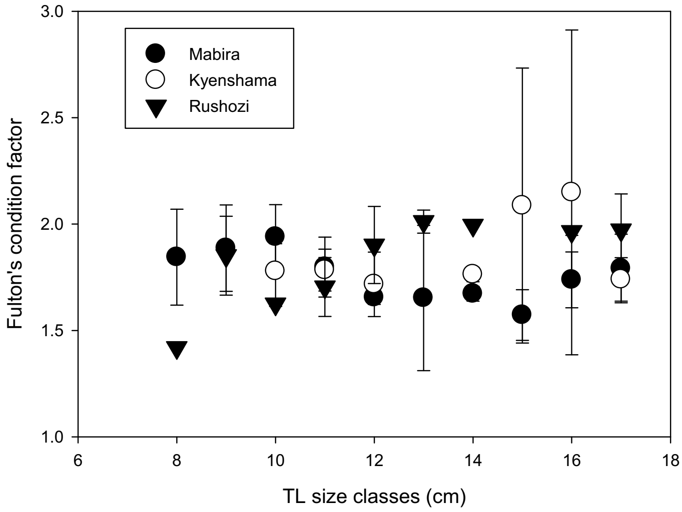
Tab. 5: Abundance (ind.m^{-2}) of macroinvertebrates in the three dams

Dams	Chironomidae	Chaoboridae	Total macroinvertebrates
Mabira	532.5 ±732.0	108.0 ±137.9	641
Kyenshama	0.0	56.6 ±89.8	57
Rushozi	9.4 ±18.9	113.2 ±134.3	123

Tab. 6: Percentage of fish species composition by dam reservoir

Fish taxa	Mabira	Kyenshama	Rushozi
Haplochromis sp.	0.0	6.0	26.3
Barbus sp.	0.0	0.8	11.9
Clarias gariepinus	0.0	0.0	0.9
Oreochromis niloticus	100.0	93.0	60.5

Figure 5: Fulton's condition coefficients for Nile tilapia size classes 7–17 cm TL



for Mabira tilapia ranged between 75 and 245 mm with a mean of 119 ± 39 mm, for Kyenshama 88–218 mm with a mean of 153 ± 40 mm and for Rushozi from 79–193 mm with a mean of 134 ± 36 mm. All the 13 African catfish recorded were from Rushozi and ranged between 165 and 588 mm TL with a mean of 134 ± 36 mm. In addition, also 271 *Haplochromis* sp. and 200 *Barbus* sp. individuals were recorded in Kyenshama and Rushozi reservoirs.

The coefficient of tilapia weight-length relationship ($W = a + L^b$) ranged from –1.62 to –1.85 (Table 7). The rate of weight increase with length ranged between 2.88 and 3.11. Fulton's fish condition coefficient differed significantly among the three dams (K-W test, $p < 0.05$).

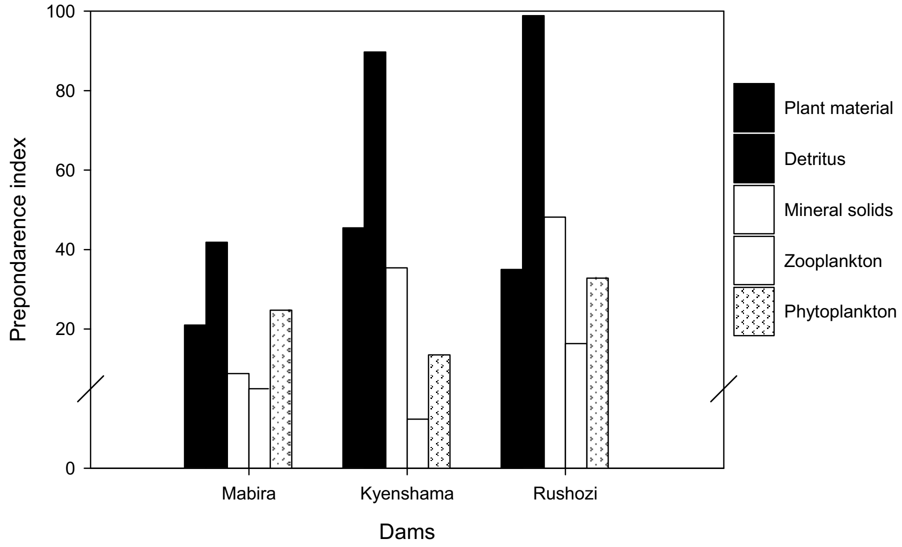
Tab. 7: Coefficients of Nile tilapia weight-length relationship and Fulton's condition coefficient (FCC)

Dam	a	b	r^2	FCC
Mabira	–1.62	2.88	0.99	1.77 ± 0.18
Kyenshama	–1.74	2.99	0.97	1.84 ± 0.36
Rushozi	–1.85	3.11	0.99	1.86 ± 0.18

Tab. 8: Food composition and selectivity index (E) in Nile tilapia diet

Food item	Mabira		Kyenshama		Rushozi	
	% weight	E	% weight	E	% weight	E
Cyanobacteria	7.7	–0.16	1.2	+0.02	5.5	–0.38
Bacillarophyceae	2.8	+0.49	2.6	+0.77	0.5	–0.30
Chlorophyceae	12.9	+0.07	1.2	–0.20	7.3	–0.22
Euglenophyceae	0.4	–0.44	2.0	+0.78	0.4	+0.80
Rotatoria	1.6	+0.92	1.5	–1	7.8	+0.07
Cladocera	1.6	+0.58	0.3	+1		
Copepoda	2.0	+0.97				
Plant material	15.6		23.3		14.7	
Detritus	41.3		46.0		41.5	
Mineral solids	14.2		21.7		22.2	
Number (n)	37		37		39	
Empty stomachs	2		0		4	
Index of filling (%)	2.8 ± 2.6		2.7 ± 3.1		2.9 ± 2.9	
Average weight (g)	39.4±44.1		77.2 ± 52.8		54.6 ± 39.5	

Figure 6: General preponderance index for Nile tilapia diet



Rushozi tilapia had highest values that differed significantly from those of Mabira fish (MCMR, $p < 0.05$). Tilapia of TL of 8–17 cm had highest mean condition coefficient in Mabira dam ranging from 1.57 ± 0.03 to 1.94 ± 0.34 > in Rushozi 1.42 ± 0.1–2.01 ± 0.18 > Kyenshama 1.71 ± 0.34 – 2.15 ± 0.76 (Figure 5).

Fish diet

Nile tilapia

The diet of Nile tilapia (Table 7) consisted of planktonic organisms (phytoplankton and zooplankton) and organic and inorganic debris. Organic particles in various stage of decomposition (detritus and plant fragments) prevailed in the stomach content contributing by more than one half to food ingested (56.9, 69.3 and 56.2% in Mabira, Kyenshama and Rushozi. The contribution of planktonic organisms was highest in Mabira reservoir (23.8 and 5.2% of phyto- and zooplankton, respectively) whilst lowest contribution was recorded in Kyenshama with 7.0 and 1.8%, respectively. The proportion of mineral solids (soil and sandy particles) amounted to 14.2, 21.7 and 22.2 in Mabira, Kyenshama and Rushozi reservoirs, respectively.

Figure 7: Feeding strategy in Nile tilapia

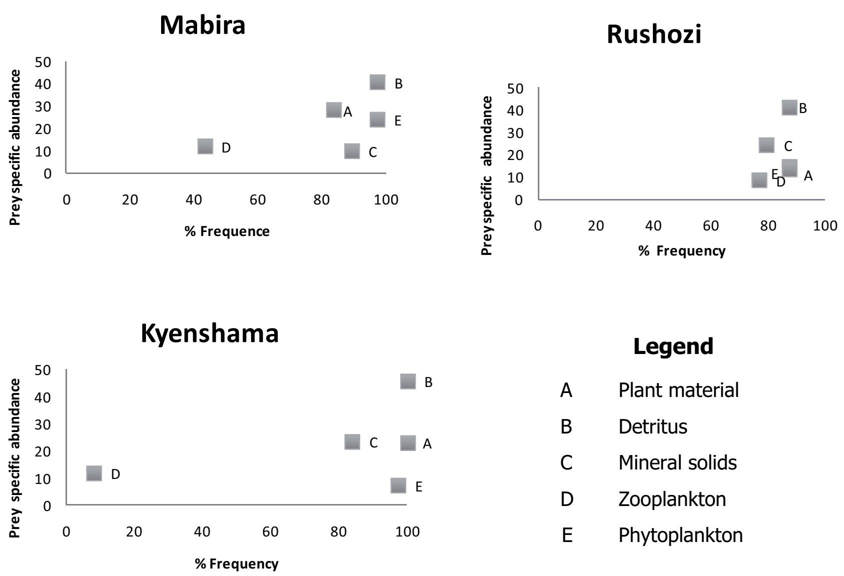
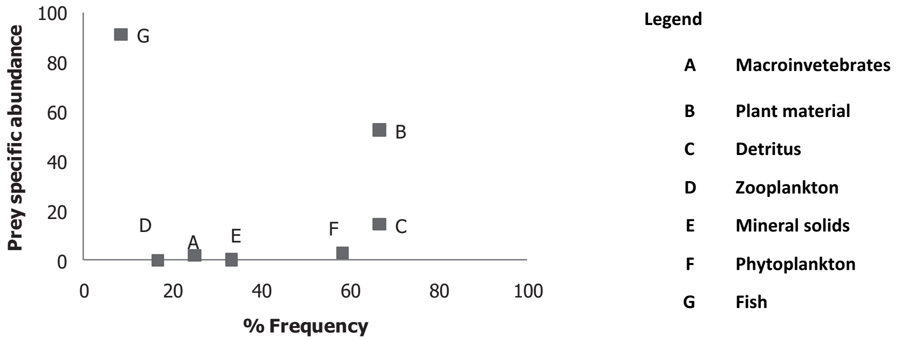


Figure 8: Feeding strategy in African catfish



Selectivity indices for phytoplankton and zooplankton indicated both avoidance and preference without any tendency with respect to reservoir or food item (Table 7). The index of stomach filling did not differ among the dams (K-W, test, $p > 0.05$).

Tab. 9: Food composition and selectivity in African catfish diet within Rushozi dam

Food item	% weight	E
Cyanobacteria	0.8	+0.9
Bacillariophyceae	0.8	+0.9
Chlorophyceae	1.3	+0.5
Euglenophyceae	0.1	+1
Rotatoria	0.01	+0.1
Ephemeroptera	0.6	+1
Chaoboridae	1.3	+0.2
Fish	47.7	–
Plant material	34.5	–
Detritus	12.7	–
Mineral solids	0.2	–
Number (n)	13.0	
Empty stomachs	5.0	
Index of filling (%)	12.5 ± 28.4	
Average weight(g)	237.8 ± 409.1	

Detritus had the highest index of preponderance in all dams (Figure 6). Its value was highest in Rushozi (98.8) > Kyenshama (89.7) > Mabira (41.9). Zooplankton was lowest but with highest index in Rushozi (16.0%) > Mabira (2.5%) > Kyenshama (0.3%). This tendency was revealed also in Costello´s graphic presentation of Nile tilapia feeding strategy – detritus, plant material and phytoplankton were the important diet items in all the three tilapia populations while zooplankton was a rare component (Figure 7).

African catfish

By frequency percentage, detritus, plant material, and phytoplankton were the three most frequent diet items, despite fish (*Haplochromis* and *Barbus*) composed close to half of the diet, seconded by plant material. Phytoplankton dominated by Chlorophyceae was still the most important live diet item compared to macroinvertebrates and zooplankton. Zooplankton was the least in composition (exclusively rotifer *Philodina* sp.). Chaoboridae was the major macroinvertebrate food item. Selectivity was found to be positive for all natural food items. Mineral solids/ inorganic silt were of negligible importance. The index of preponderance showed a different pattern with highest preponderance for plant material, followed by detritus, fish and phytoplankton.

Tab. 10: Food coincidence between tilapia and catfish in Rushozi dam

Food item	% in tilapia	% in catfish	Coincidence (%)
Macroinvertebrates	0.0	1.9	0.0
Plant material	14.7	34.5	14.7
Detritus	41.5	12.7	12.7
Zooplankton	22.2	0.0	0.0
Mineral solids	7.8	0.2	0.2
Phytoplankton	13.8	2.9	2.9
Fish	0.0	47.7	0.0

As evident from Figure 8, plant material, detritus and phytoplankton were three most important diet items; however some individuals specialised on fish as a target prey.

Food coincidence

A total coincidence between Nile tilapia and African catfish was 33.2% mainly due to plant material and detritus (14.7 and 12.7 %, respectively). The only coincidence for natural food items concerned phytoplankton with 2.9%.

DISCUSSION

Physico-chemical characteristics

With reference to nutrients (TP&TN), all dams were eutrophic tending to hypertrophic and therefore highly productive and good for semi-intensive fish production (Table 2 and 3). Based on Jeffries and Mills (1990) argument, the N:P ratios are preferably good indicators of productivity, Mabira and Rushozi were phosphorus limited (N:P > 9) while Kyenshama was nitrogen limited (N:P < 9). This was an indicator of likelihood in dominance of the indigestible and unpalatable cyanobacteria that are not efficiently utilised by fish. Anoxic conditions in Kyenshama enabled the phosphorus release from complexes while the high oxygen in Rushozi and Mabira made it retained in sediments with low availability for phytoplankton growth. This emphasises the low oxygen levels in this dam making it unsuitable for more fish biomass in the current state. The difference between TSS (105°C) and TSS (500°C) showed that the highest ash-free organic matter was in Rushozi indicating likely high quality food resources (detritus or plankton). This was confirmed by coincidence with high algal biomass based on Chl-*a* concentrations making it a more productive reservoir due to high abundance of food resources. Chl-*a* results showed the highest algal biomass was in Rushozi and lowest in Kyenshama thus explaining the observed opposite trends on physico-chemical water properties due to reverse process intensity. High oxygen saturation, turbidity, pH and low Secchi depth (0.24 m) in Rushozi were clearly due to high primary production. An opposite trend was observed in Kyenshama although might have been complexed by the littoral and submerged macrophytes which seemed to dominate primary production with consequences in low phytoplankton abundance and high decomposition rates that led to low dissolved oxygen concentration. On the other hand, being the shallowest (2.6 m) and unsheltered, Rushozi was well exposed for wind induced mixing with recovery of nutrients for primary production and had thus attained its equilibrium as a turbid state dam reservoir dominated by phytoplankton suitable for phytoplankton-feeding fish. From this mixing, both plankton and resuspended sediments were therefore responsible for the nephelometric turbidity and low Secchi depth which on the other hand could affect feeding rates of zooplankton and fish. Fisheries technologies leading to further enrichment such as intensive cage farming may not be suitable for Rushozi but preference would go for those that can utilize the current phytoplankton stock if water quality both for livestock and fish production are to be sustained.

On the other hand, comparably low temperature in Mabira reservoir seemed to be influenced by altitude being a "rangeland dam" (located at the hill top and thus also the high alkalinity and conductivity due to geological mineral content). The associated calcium and magnesium carbonate hardness made the dam more buffered for a stable pH which together with the low temperature (22°C) favoured most zooplankton groups making it suitable for zooplanktivorous fishes. The nutrient imbalance might have been complexed by the papyrus littoral beds in some way since according to Moss (1988) they are effective in taking up nutrients especially from agricultural runoff.

Phytoplankton

Phytoplankton comprised of four major categories. Cyanobacteria, Bacillarophyceae, Chlorophyceae and Euglenophyceae (Table 4) was mostly favoured in Rushozi with chlorophyts and cyanobacteria dominating, which could be an early indicator of nutrient imbalance as suggested by the N:P ratio thereby having a competitive advantage over others. Dominance was however not strong in Kyenshama, categorical phytoplankton density variability was low despite the thick decaying plant leaf "mat" at the bottom.

Phytoplankton abundance in Rushozi (1.24×10^5cells per ml) coincided with high chlorophyll *a* (220 $\mu g.l^{-1}$) concentrations, high oxygen (99%), low Secchi depth (0.23 m), high turbidity and total nitrogen limitation characteristic of productive eutrophic lakes confirming its suitability for semi-intensive culture systems where feeding costs can be reduced by supplementation from natural organisms.

The low phosphorus levels in Kyenshama reduced excessive primary production giving equal opportunity to all phytoplankton categories to flourish with almost similar density including Euglenophyceae and Bacillariophyceae – highly nutritive and digestible taxa.

Zooplankton

The turbulent mixing and resuspended solids in Rushozi are known to be detrimental to cladocerans affecting their filter feeding and reproduction. It is not therefore surprising that Mabira which had less association with these interferences had higher abundance of cladocera and would be suitable for omnivorous fish.

The physico-chemical conditions in Mabira seemed to be more conducive for zooplankton especially temperature, light and the ionic content. The high carbonate alkalinity provided stable pH for physiological processes but however, the small size structure composition is of great concern in food and environmental quality consideration. All dominating zooplankton taxa (*Ceriodaphnia*, *Brachionus* and *Cyclops* copepodite and nauplii stages) are known to be among the smallest of their categories. The occurrence of cladoceran *Ceriodaphnia* particularly in Mabira could have been closely related to its optimum growth water temperature requirement (20–22ºC), its reproduction and feeding are known to be reduced considerably above 22ºC (Gophen, 1976) however the phytoplankton quality might have also played a role since high densities clog the filtration apparatus. It is not clear whether fish predation pressure was responsible for this structure since *Ceriodaphnia* are smaller (0.4–1.4 mm) than *Daphnia* species and therefore less ingested than the more obvious daphnia. They avoid open water during day because of competitive daphnia however, Lauridsen et al. (1999) found them in more numbers where fish stocks were relatively high. Therefore absence of bigger cladocera species may be indicative of grazing pressure from fish and invertebrates and in such a case would give little room for more fish biomass. The dams can however support wild based quality tilapia fry production and nursery operations especially in Rushozi where copepods were not encountered. The dominant *Brachionus* family is associated with eutrophic waters considering that they feed on detritus thus was found most in Rushozi due to high primary production. These small zooplankton species are also very sensitive to toxicity and therefore may on the other hand be based on to rule out the adverse effects of acaricides specifically in Mabira dam where cows did not drink directly from the dam.

Macrozoobenthos

The exclusive habitation by chaoborids though good macroinvertebrate food for fish was a clear indicator of prolonged anoxic conditions and associated sulphur reduction (hydrogen sulphite as a toxic substance) that could have been to intolerable levels for the benthic chironomids.

Because of their adaptability to low oxygen chironomids and chaoborids are major inhabitants of standing waters which are in most cases eutrophic (Maitland, 1978). They are highly preferred food for benthic feeding fish, however the comparably low but diverse/balanced densities in Rushozi dam could be explained by the poor solid and hard bottom substrate compared to Mabira dam. In Kyenshama, the anoxic thick mat of submerged and decaying *Ceratophyllum* macrophyte made conditions persistently anoxic (as observed in water column oxygen levels), favouring the hardy chaoborids being planktonic (Lo'pez and Zoppi de Roa, 2005) over chironomids which activity is known to cease under completely anaerobic conditions.

Fish

The dominance of Nile tilapia could be related to past-stocking regimes during the 1950's. The by-catch was thought to have been self-stocked from flooding events that recharge these dams with the V-shaped valley of Mabira being closed water shed with little inflows. The differences in mean weight could not be articulated unless aging studies are done to rule out stuntedness in Mabira. The weight was highly positively correlated to total length (r^2 values of 0.97–0.99.) i.e. over 97% of weight could be explained by total length. The rate of increase of weight with length was almost similar and about 3 in all fish implying same fillet quality when marketing is considered.

Fish showed better general condition in Rushozi due to rich food abundance. In Mabira, the condition was reduced with increasing size indicating spawning at small size compared to fish in Rushozi which condition was still increasing within 7–11cm size range thus making it a better brood stock source for prospective quality seed producers. The trend in Kyenshama was not clear due to inconvenient environmental conditions.

Rushozi dam reservoir provided more food than Mabira and Kyenshama however its selectivity seemed to depend on food size/quality as shown by a more positive selection for phytoplankton in Mabira other than in Rushozi where the water plankton was dominated by large colonies of *Microcystis*, long filaments of *Anabaena* and the spiny *Ankistrodesmus* yet stomach contents were dominated by *Gomphosphaeria, Scenedesmus* and *Merismopedia.*

Zooplankton was mostly negatively selected because of being of small size in addition to motility and not strategically positioned in the upper water surface where conditions are favourable for fish feeding. Based on the optimum feeding theory, tilapia spends less energy through ram-ventilation filtration and therefore not surprising that detritus, plant materials and phytoplankton were the dominant diet items for tilapia across the three dams. Apart from abundance it might have been related to low energy requirements and searching time during feeding since these items occupy relatively stable positions compared to zooplankton.

Nile tilapia is a planktonic filter feeder and therefore macroinvertebrates did not form any part of its diet, however the source of high mineral/inorganic solids in its diet remains unclear. Because detritus is a product from either flora or fauna it could be a major source of organic matter for detrivorous fish (Bowen, 1984) like tilapia in this case.

African catfish in Rushozi was an omnivorous fish feeding at all levels. Fish contribution in catfish diet was important to a few individual fish based on weight but not on frequency thus the traditional plant material, detritus and phytoplankton remained the major diet items with inclusion of benthic macroinvertebrates. This supported the findings of Adámek and Sukop (1995), who considered African catfish as generally "feeble predators" since the available fish was not a stable diet item except in a few individuals that seemed to specialize on fish prey. In this study it was not clear why chironomids were not consumed by catfish.

The exclusive positive selection for diet items in African catfish compared to Nile tilapia is to be explained by their higher feeding activity when searching for food. Potential effective competition with tilapia was considerably low (only about 3%) and concerned exclusively phytoplankton since detritus and plant material were not limiting and considered of low nutritional value. Therefore mixed culture of the two species in these dams would ensure maximum resource utilisation and probably reduction of nuisance cyanobacteria thus keeping the water quality acceptable for livestock watering.

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