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Full Length Research Paper

A Study of Physicochemical Parameters, Zooplankton and Macro-invertebrate Compositions and Abundances as Water Quality Indicator in Selameko Manmade Reservoir, Debre Tabor, South Gondar, Ethiopia.

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Abstract
Physicochemical properties, zooplankton and macro-invertebrate compositions and abundances were investigated for one year between August 2009 and May 2010, to know the water quality status based on the physicochemical parameters, zooplankton and macro-invertebrate compositions and abundances in Selameko manmade reservoir, Debre Tabor, South Gondar, Ethiopia. Physicochemical parameters were measured in-situ using standard methods. Zooplanktons and macro-invertebrates compositions and abundances were analyzed in Tana fisheries and other aquatic organisms' research center. Reservoir water temperature ranged from 18.7 to 24.2°C,water depth (only for open zone) 10.5m to 13.04m, pH 7.01 to 8.01, dissolved oxygen 5.0 to 6.15 mg/l, transparency depth 32 to 97cm, TDSs 67.1 to 137.2 ppm, NO_3-N 0.1 to 2mg/l, PO_4-P 0.08 to 0.83mg/l and Silicate 0.09 to 22.5mg/l. A total of 16 genera from 3 taxonomic groups of zooplanktons and a total of 6 groups, representing 7 orders and families of macro-invertebrates were identified. ANOVA result of the physicochemical parameters, zooplanktons and benthic macro-invertebrates showed significance difference among seasons and between sites ($p<0.05$). The study concluded that some of physicochemical parameters (NO_3-N and PO_4-P) indicated the presence of reservoir water pollution, which is supported by existence of pollution resistant zooplankton, Bosmina and macro-invertebrates species Chironomidae. These species also indicated eutrophic status of the reservoir water. To avoid such pollution, basin and reservoir management are recommended.

Key words: *Zooplankton, Macro-invertebrates, Water quality, Physico-chemical Parameters, Pollution*

Introduction

Zooplankton are an important component of the aquatic biota and play a crucial role in the food web (Gannon & Stemberger 1978) by forming a link between the lower trophic level (phytoplankton) and the higher trophic level organisms such as macro-invertebrates and fish (Paterson 2001; Alcara & Calbet 2008). The assemblage of zooplanktons often influences nutrient cycling and community population dynamics within a reservoir ecosystem (Carpenter & Kitchell 1993). Besides, the species composition, distribution, diversity and relative abundance of zooplankton of a reservoir could have significant impact on fisheries and public health of the reservoir and its users (Hecky & Kling 1981).

Zooplankton are susceptible and affected by various and a wide number of environmental factors (e.g., light, salinity, toxic contaminants), physicochemical parameters, and food availability (primary production) (Satsmadjis 1985; Paterson 2001; Alcara & Calbet 2008). Because these nature, the assemblages zooplankton may be considered as bio-indicators of eutrophication, and considerable potential value as water quality indicators (Gannon & Stemberger 1978; Sladecek, 1983; Francis et al. 1998).

Benthic macro-invertebrates are also those organisms that live on or inside the deposit substratum at the bottom of a water body (Idowu & Ugwumba 2005). They are know by linking the unavailable nutrients in detritus to useful protein materials in fish and shell fish because they feed on detritus that settle on the bottom of the water and in turn serve as food for a wide range of fishes (Adebisi 1989; Ajao 1990; Oke 1990). Furthermore, they accelerate the breakdown of decaying organic matter into simpler forms like phosphates and nitrates (Gallep et al. 1978).

Similar to zooplankton communities, benthic macro-invertebrates have been one of the most widely used groups of organisms for evaluating the quality of a certain waters bodies (Olive & Dambach 1973; Roback 1974; Hellawell 1986). Characteristic changes in benthic invertebrate communities (species composition and the relative abundance of each species) occur in response to changes in temperature regimes, to alterations in erosional and siltation patterns, and to changes in concentration of domestic or industrial wastes. The nature and magnitude of the community alteration depends upon the nature and severity of the environmental change (Olive & Dambach 1973) and these qualitative and quantitative changes in the benthic communities have also been used as a tool for checking pollution through the use of indices (Dhillon et al. 1995; Tyagi 2006). Totally, benthic communities with a large proportion of pollution-sensitive organisms usually are associated with water of relatively high quality; whereas large proportions of pollution-tolerant organisms (numerous families) have indicated water badly polluted with organic wastes (Olive & Dambach 1973; Goethals & Pauw 2001; Flotemersch et al. 2006; Tyagi 2006).

In conclusion, the presence or the absence of these species can be an indicative of the disturbance of ecosystems (Chapman 1989). Both zooplankton and macro-invertebrate communities, living directly under the influence of a specific physical and chemical environment, closely reflect the alterations in water quality. The aim of this work was to know the reservoir water quality by studying the physicochemical parameters, zooplankton and macro-invertebrates communities in Selameko manmade reservoir, Debre Tabor, South Gondar, Ethiopia.

Materials and Methods

Description of the Study Area

This study was conducted at Selameko manmade reservoir, south-west of Debre tabor town, Ethiopia. This manmade reservoir is found 2513 m (above sea level), specifically located at 38° 05' E and 11° 53' 24" N (Figure 1). The reservoir was constructed in 2007 with a total of 11.6 hectares (ha) to irrigate nearly 63 ha of agricultural land. The catchments are extended from 2513 to 2726 m (above sea level) with a total of 879.25 ha of lands.

Hydrology and Climate: The study areas mean annual temperature and rainfall is 16.23 ^{o}C (ranges from 9.2^{o}C - 23.26^{0}C) and 1371.2 mm (ranges from 1096.7 mm - 1645.7 mm) respectively. The reservoir water fluctuate was mainly depending on inflows direct from the sky and the catchments during rainy season, and supply from Selameko river; and outflows connect with releasing water for irrigation and dam crack, and direct evaporation of reservoir water. Because of these unbalance, the water depth was decreased 2.54 meters. The climate of reservoir is characterized roughly by four seasons: (1) A main-rainy season (MRS) with heavy rains during July–September, (2) a post-rainy season (PORS) between October–November, (3) a dry season (DS) between December–April and (4) a pre-rainy season (PRS) from May–June (Tamiru 2006; Ayalew et al. 2007).

Measurements of Physicochemical Parameters

Physicochemical samples were collected in one year, from August 2009 to May 2010 in the four seasons, i.e., main rainy, post-rainy, dry and pre-rainy seasons. The water samples were taken only from littoral (SI) and open water zone (SII) two times from each for each parameter (Figure 1).

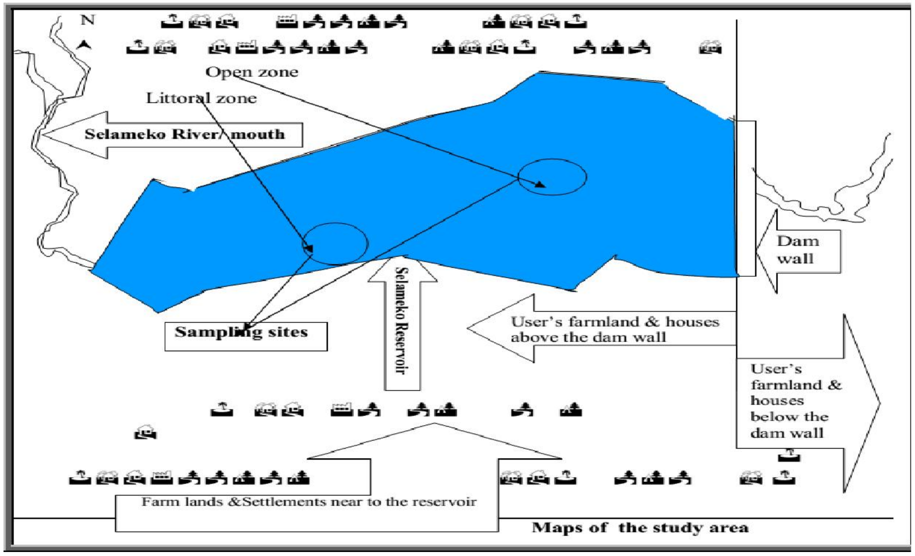

Figure 1: Map of the study area (Selameko Manmade Reservoir).

Water temperature and pH, dissolved oxygen (DO), total dissolved substances (TDSs) and water transparency were determined in-situ. Water temperature and pH were measured with coupled pH/TDS/CON Meter (Model Tochpro II); DO was determined by portable oxygen analyzer (JPB-607); TDSs were measured by cond/TDS meter (Model CE 470 Cond. Meter 01189); water depth was measured by standardized meter and transparency was measured by standardized Secchi disc (having white and black color with 25 cm in diameter). Major nutrients, nitrate (NO_3-N), phosphate (PO_4-P) and silicate (SiO_2) were measured in-situ immediately by using a portable water analyzer kit (Wagtech International, Palintest transmittance display photometer 5000, Palintest Ltd., and UK) (Palintest Ltd. 1989). The collected water samples from the two sites were first filtrate by Whatman GF/C, 0.6-0.7-µm.

Measurements of Zooplanktons and Benthic macro-invertebrates

Zooplankton: Integrated zooplankton samples were collected two times for each from both littoral and open zone using of Van Dorn water sampler. The collected 20 liter samples were concentrated into 50ml by filtering 80 µm (mesh opening) of zooplankton net; and then preserved with neutralized formalin solution (40% of formaldehyde) (Wetzel & Likens 2000). Identification and counting were made using Euromex compound microscope (40X) according to the key guideline of Fernando (2002). Abundance of each species of zooplankton was calculated based on Lind (1979). Benthic macro-invertebrates: Benthic macro-invertebrates were sampled with an Ekman bottom sampler (dredge) at littoral only where physicochemical parameters were taken. Samples were poured through a 500µm sieve and then preserved in 90% ethanol and returned to the laboratory for further identification and enumeration (Wetzel & Likens 2000). Each macro-invertebrate (size > 500µm) were identified in their lowest group (family level) based on the key guideline made by Merrit and Commons (1996), Mandeville (2002) and Bouchard (2004). Counting was done using Euromex compound microscope (40X) and gridded glass counting chamber having 24 grids.

Data Analysis

Analysis of variance (ANOVA) was used to test significant differences between those like spatial and temporal variations of physico-chemical and biological parameters ($P<0.05$). Tukey (Honestly Significantly Differently Test) test was used to determine significance in mean catches and estimates. Stepwise regression was used to test the relationship between the physico-chemical parameters and biological variables; the observed (r) values were then compared to the table values at $P < 0.05$ level of significance; whereas abundance of zooplanktons and macro-invertebrates were analyzed using percentage. In general, data were calculated and organized using appropriate statistical software, such as the SAS (2003) and SPSS (2007) version 16.

Results

Physicochemical measurements (in Seasons and Sites)

These are presented in Table 1. Both spatial and temporal fluctuations were recorded among the limnological variables and these are agreed with ANOVA ($P<0.05$) and Tukey tests ($P<0.05$) (Table 1 & 2). Additionally, the interactions of site and season with physicochemical parameters were significant, except pH (Table 2). Temperature of the reservoir water ranged minimum of 18.7°C to maximum of 24.2 °C. The water depth ranged 10.5 m (pre-rainy season) to 13.04 m (main rainy season) in open zone. pH of the reservoir extended between 7.01 to 8.01. DO range from 5.0 mg/l to 6.15 mg/l. The transparency depth varied from 32 to 97 cm. TDSs was between 67.1ppm and 137.2 ppm). The amount NO_3-N varied 0.1 (dry season) to 2 mg/l (main rainy season) and these results, the highest (2 mg/l) and the lowest (0.1 mg/l) were recorded in open water zone. Concentration of PO_4-P ranged from 0.08 mg/l (post rainy season, open water zone) to 0.83mg/l (littoral zone, main rainy season); and SiO_2 concentration varied from 0.09 (open zone) to 22.5mg/l (littoral & open zones). In both sites, the maximum and the minimum values of silicate were recorded in main rainy season.

Table 1: Physico-chemical parameters of Selameko Reservoir from August 2009 to May 2010. (The mean differences of (Tukey Test) physico-chemical parameters.)

Physico-chemical parameters	**SI**					**SII**				
	Season I					**Season II**				
	MRS	**PORS**	**DS**	**PRS**	**Av ± SD**	**MRS**	**PORS**	**DS**	**PRS**	**Av ± SD**
T°C	20.0^{d}	18.7^{e}	24.2^{a}	23.1^{b}	21.5± 1.28	19.7^{d}	20.8^{c}	24.2^{a}	24.1^{a}	22.2 ± 1.16
pH	7.72^{ab}	8.01^{a}	7.42^{bc}	7.59^{b}	7.69± 0.12	7.42^{bc}	7.39^{bc}	7.01^{d}	7.22^{cd}	7.26± 0.094
DO (mg/l)	5.59^{bc}	5.9^{ab}	5.1^{d}	5.3^{cd}	5.47± 0.17	6.15^{a}	5.9^{ab}	5.0^{d}	5.2^{cd}	5.56± 0.27
WTD (cm)	32^{f}	67^{c}	62^{cd}	40^{e}	50.25± 8.46	42^{e}	97^{a}	89^{b}	60^{d}	72±12.72
TDSs (ppm)	98.4^{c}	67.1^{f}	74.3^{e}	87.4^{d}	81.8 ± 6.94	137.2^{a}	67.1^{f}	90.43^{d}	114.3^{b}	102.26± 15.11
NO_3-N (mg/l)	1.85^{b}	0.21^{ef}	0.25^{e}	0.53^{d}	0.71±0.34	2.0^{a}	0.22^{e}	0.10^{f}	0.71^{a}	0.758±0.43
PO_4-P(mg/l)	0.83^{a}	0.12^{cd}	0.44^{b}	0.16^{cd}	0.388±0.26	0.45^{b}	0.24^{c}	0.24^{c}	0.08^{d}	0.253±0.075
SiO_2 (mg/l)	22.5^{a}	6.81^{c}	2.24^{d}	0.66^{e}	8.05±4.98	22.5^{a}	10.06^{b}	2.08^{d}	0.09^{f}	8.68±5.08

N.B: *Means of the two columns of a particular parameter followed by the same letter (s) are not significantly different from each other ($P<0.05$, Tukey HSD). (Average ± SD). Abbreviations used: Average= Av, SD = standard deviation, WTD= water transparency depth.*

Table 2: Effects (effect test) of Sites and Seasons on the Physicochemical Parameters.

Limnological Parameters	**Factors**	**Degree of Freedom (df)**	**Sum of square**	**F-ratio**	**Prob..> F**
Temperature	Sites	1	1.96	52.27	<.0001
	Season	3	67.98	604.27	<.0001
	Sites* Season	3	3.54	31.47	<.0001
pH	Sites	1	0.72	91.17	<.0001
	Season	3	0.53	22.23	0.0003
	Sites* Season	3	0.06	2.39	0.1440
Dissolved Oxygen	Sites	1	0.03	2.55	0.1487
	Season	3	2.23	55.52	<.0001
	Sites* Season	3	0.31	7.40	0.0108
Transparency	Sites	1	1892.3	630.75	<.0001
	Season	3	5392.81	599.19	<.0001
	Sites* Season	3	236.75	26.31	0.0002
Conductivity	Sites	1	6.56	136.72	<.0001
	Season	3	1591.07	947.06	<.0001
	Sites* Season	3	363.57	216.41	<.0001
Total Dissolved Substance	Sites	1	1674.04	2470.90	<.0001
	Season	3	5827.21	2867.02	<.0001
	Sites* Season	3	815.1 9	401.08	<.0001
NO3-N	Sites	1	0.01	10.31	0.0124
	Season	3	8.05	3067.91	<.0001
	Sites* Season	3	0.07	26.09	0.0002
PO4-P	Sites	1	0.07	47.80	0.0001
	Season	3	0.65	141.99	<.0001
	Sites* Season	3	0.13	28.92	0.0001
SiO2	Sites	1	1.58	146.67	<.0001
	Season	3	1209.20	37385.96	<.0001
	Sites* Season	3	9.33	288.57	<.0001
Chlorophyll-a	Sites	1	13.18	7.49	0.0256
	Season	3	1036.16	196.24	<.0001
	Sites* Season	3	256.08	48.5007	<.0001

Biological Characteristics in Seasons and Sites

Zooplankton Compositions and Abundances: Check lists of zooplankton compositions and abundances from August 2009 to May 2010 are presented in Table 3. In general, a total of 3 taxa and 16 genera of zooplanktons were recorded. In both sites, the observed dominant genus was *Keratella* in pre-rainy season (littoral zone) & in dry season (open zone). At class level, *Rotifera* (56.61%, littoral & 68.86%, open zone) was the highest; and *Cladocera* (16.57%, littoral & 14.71%, open zone) was the least. Among seasons, pre-rainy season zooplanktons (73.77%, littoral zone) was the highest followed by dry season (60.16%, open zone) and dry season zooplankton was the least (1.56%, littoral zone). According to stepwise regression, the total number of zooplanktons had showed negative relation with some physicochemical parameters (R2 = 0.91, P< 0.05, N= 16). Grand total of zooplanktons = -909.41 PO_4-P, -21.45 SiO_2, -35.49 temperature. Except *Rotifera* (between sites), the ANOVA result showed that there were highly significant difference in cladocera, and copepoda among seasons and between sites (Table 4). The Tukey test result showed this truth (Table 5). Also, zooplankton showed significant interaction with sites and seasons, except rotifer (Table 5).

Benthic Macro-invertebrate Compositions and Abundances: As presented in Table 4, a total of 6 classes, representing 7 orders of macro-invertebrates were identified in littoral zone only. From the whole classes, Nematoda was the most abundance (49.32%), only found in dry season, and Gastropoda (0.25 %) was the least representative. Across seasons, dry season (63.87%) was the most abundance and rich in family compositions, but no any types of macro-invertebrates were in pre-rainy season. According to the stepwise regression, the total number of benthic macro-invertebrates had both positive and negative relation with few physicochemical parameters (R2 = 0.99, P< 0.05, N= 8). Grand total of benthic macro-invertebrates = -1.4 secchi depth, + 926.39 PO_4-P, -12.75 TDS. The ANOVA result showed that there were highly significant differences at family level, except Bivalves (Table 4). The Tukey test showed this truth (Table 5).

Table 3: Seasonal and temporal abundance (ind/l) Zooplankton Selameko reservoir (August 2009- May 2010).

Zoolpankton genera	**MRS**		**PROS**		**DS**		**PRS**		**Total**	
	SI	SII	SI	SII	SI	SII	SI	SII	SI	SII
ROTIFERA										
Keratella	4.7	1.9	-	-	2.2	181.7	225.8	15.9	232.6	199.4
Brachionus	12.9	7.7	3.2	1.5	-	0.5	3.2	1.8	19.3	11.5
Asplanchna	0.4	0.2	-	-	-	0.2	2.6	-	2.9	0.4
Polyarthra	0.2	0.2	0.2	-	0.2	1	1.5	1.1	0.6	2.2
Hexarhtra	0.7	-	-	-	-	1.7	-	10.5	0.7	12.2
Cephalodela	2.1	2.4	-	-	-	-	-	-	2.1	2.4
Filinia	-	-	-	-	-	-	3	3.9	3	3.9
Trichocera	-	-	-	-	-	-	1.35	0.5	1.4	0.5
Total	56.3	35.8	3.9	6.6	0.6	3	16.5	4.2	77.3	49.6
% Rotifera	8.0	5.3	1.3	o.6	0.8	79.6	89.9	14.5	56.6	68.9
CLADOCERA										
Alona	-	-	-	-	0.2	0.2	-	-	-	0.2
Bosmina	5.5	0.8	-	-	-	-	0.2	0.5	5.6	1.4
Moina	3.4	2.6	0.6	0.9	-	0.2	2.3	1.7	6.4	5.3
Daphnia	0.2	3.7	6.9	-	0.3	2.1	2.9	0.9	6.2	10.1
Ceriodaphnia	39.8	20.9	3.2	5.6	0.2	0.2	11.3	1.2	54.3	28.2
Diphanosoma	3.9	4.5							3.9	4.5
Total	56.3	35.8	3.9	6.6	0.6	3	16.5	4.2	77.3	49.6
% Cladocera	72.6	72.2	5.0	13.3	0.8	6.0	21.3	8.5	16.6	14.7
COPEPODA										
	0.5	0.1	-	0.4	0.2	-	-	-	0.7	0.5
Cyclopoid	21.1	14.1	9	17.8	4.2	15.2	90.2	7.9	124.5	55
Total	21.6	14.2	9	18.2	4.4	15.2	90.2	7.9	125.2	55.5
% Copepoda	17.3	25.6	7.2	32.8	3.5	27.4	72	14.2	26.8	16.4
Grand total	1 98.8	62.4	16.2	26.2	7.3	203.1	343.9	45.75	466.4	337.5
Total № of genera	14	12	6	6	8	13	12	11		
Percentage abundance	*21.2*	*18.5*	*3.57*	*7.75*	*1.56*	*60.16*	*73.77*	*13.72*	*100*	*100*

N.B: '-' = Implied absence; littoral = SI; and open = SII

Table 4: Seasonal Abundance (Ind/m^2) and Composition of Identified Macro-Invertebrate Littoral Zone in Selameko Reservoir (from August 2009- May 2010).

Class	**Order**	**MRS**	**PROS**	**DR**	**PR**	**Total**	**% Abundance**
		SI	**SI**	**SI**	**SI**	**SI**	
Oligocheata	Oligocheata	-	3	80	-	83	10.23
Hirudinea	Hirudinae	-	3	4	-	7	0.86
Insecta	Coleoptera	-	-	8	-	314	38.71
	Diptera	78	203	25	-		
Gastropoda	Gastropidea	-	1	1	-	2	0.25
Branchiopoa	Cladocera	-	5	-	-	5	0.62
Nematoda	Nematoda	-	-	400	-	400	49.32
Total		78	215	518	-	811	100
Total № of the family		1	5	6	-		
Percentage abundance (%)		9.62	26.51	63.87	-	100	

N.B: *'-' = implied absence*

Table 5: The Mean Differences of (Tukey Test) Zooplankton and Macro-benthic Organisms of Selameko Reservoir (from August 2009- May 2010).

Biological Parameters	**Seasons**	**Location**	
		Littoral zone	**Open zone**
Rotifera	Main-rainy	21.02c	12.39c
	Post-rainy	3.3c	1.5c
	Dry	2.3c	184.9b
	Pre-rainy	237.3a	33.6c
Cladocera	Main-rainy	56.27a	35.84b
	Post-rainy	3.9c	6.6c
	Dry	0.6c	3.0c
	Pre-rainy	16.5c	4.2c
Copepoda	Main-rainy	21.54b	14.19cd
	Post-rainy	9.0de	18.15bc
	Dry	4.35e	15.15bcd
	Pre-rainy	90.15a	7.95de
Copepoda	Main-rainy	21.54b	14.19cd
	Post-rainy	9.0de	18.15bc
	Dry	4.35e	15.15bcd
	Pre-rainy	90.15a	7.95de
Oligocheatae	Main-rainy	0.00c	-
	Post-rainy	3.00b	-
	Dry	80.00a	-
	Pre-rainy	0.00c	-
Hirudinae	Main-rainy	0.00b	-
	Post-rainy	3.00a	-
	Dry	4.00a	-
	Pre-rainy	0.00b	-
Beetles	Main-rainy	0.00b	-
	Post-rainy	0.00b	-
	Dry	8.00a	-
	Pre-rainy	0.00b	-
Chironomidae	Main-rainy	78.00b	-
	Post-rainy	203.00a	-
	Dry	25.00c	-
	Pre-rainy	0.00d	-
Bivalve	Main-rainy	0.00a	-
	Post-rainy	1.00a	-
	Dry	1.00a	-
	Pre-rainy	0.00a	-
Brachionidae	Main-rainy	0.00b	-
	Post-rainy	5.00a	-
	Dry	0.00b	-
	Pre-rainy	0.00b	-
Namatodes	Main-rainy	0.00b	-
	Post-rainy	0.00b	-
	Dry	400.00a	-
	Pre-rainy	0.00b	-

Means of the two columns of a particular parameter followed by the same letter (s) are not significantly different from each other (P=0.05, Tukey HSD). : '-' implied identification was not made in SII (open zone).

Discussion

Limnological Characteristics of Selameko Reservoir

Temperature of the reservoir varied from 18.7°C to 24.2 °C. This low temperature during the post rainy season was probably due to the presence of cloud that reduced sun radiation (Onyema 2007), the presence of high humidity and wind in the surrounding (Atobatele & Ugwumba 2008). The higher temperature recorded in dry and pre-rainy season was due to clear atmosphere (the absence of rain), greater solar radiation, and low water level (Moundiotiya et al. 2004). These registered low water temperature are not similar to other African reservoirs (Akindele & Adeniyi 2013). The water depth of open zone was ranged 10.5 (pre-rainy) to 13.04 m (main rainy season). The deepest was due to the high rainfall and the high surface water inflow from upstream surrounding area (river) (Asriningtyas et al. 2005; Meesukko et al. 2007); and the lowest depth was due to the presences of high evaporation, releasing of water for irrigation and dam crack. Because of reduction of 2.54m water level, poor percentage of zooplanktons and few family numbers of macro-invertebrates were registered in dry season. pH of the reservoir extended from 7.01(open zone) to 8.01(littoral zone) and tilted towards alkalinity. This pH value is good for aquatic life and falls (Oso & Fagbuaro 2008) within the EPA Redbook recommended range for fresh water (6.5- 9.0) (Schmitz 1996) and recommended by others (Goldman & Horne 1983; Chapman 1996; Joint Nature Conservation Committees 2005), and indirectly indicated the presence of sufficient zooplankton food (Chlorophyll-a concentration was between 11.02- 39.29 µg/l, Table 1). DO was between 5.0 and 6.15 mg/l. These DO concentrations satisfied the minimum recommended standard (> 5 ppm) set by EPA Redbook and others (Heiskary & Markus 2003, 2001; USEPA 2008; Yajurvedi 2008) and good for both aquatic lives.

The transparency depth varied from 32 (main rainy season, littoral zone) to 97 cm (post rainy season, open zone). The lowest was due to the presences of high surface water inflow (flooding) that contained suspended matter in main rainy season. These suspended cause to increased water turbidity and reduced transparency depth in the main rainy season (Rafique et al. 2002; Meesukko et al. 2007), again heavy rainfall increase in phytoplankton abundance by providing sufficient nutrients and decay of organic matter in suspension (Mustapha & Omotosho 2005; Atobatele & Ugwumba 2008). However, these suspended materials in rainy season had no any effect on zooplankton community as compared to other seasons, but had an influence on macro-invertebrates. Likewise, TDSs (67.1- 137.2 ppm) is very conducive for the growth of aquatic organisms (Karai et al. 2008; Mohamed et al. 2009).

The concentration of NO_3-N varied from 0.1 to 2 mg/l. The highest concentration of NO_3-N was connected nutrients come from the surrounding agricultural areas (Mustapha & Omotosho 2005; Meesukko et al. 2007) and the leachates of municipal wastes, disposal sites and sanitary landfills (Chapman 1996; Bennett 1998). The occurrence of high value of nitrate was confirmed by presence of organic pollution resistant Chironomidae (Bennett 1998) and high concentration of chlorophyll-a (11.02-39.29µg/l). Generally, the recorded NO_3-N fulfills the minimum level of nitrate in lake to be productive (< 5mg/l) (Yajurvedi 2008) and indicates the productivity of the reservoir. The amount of PO_4-P was between 0.08 and 0.83 mg/l. The highest value in main rainy season was due run-off from surrounding agricultural areas (Mustapha 2008; Oso & Fagbuaro 2008; Granit & Lindstrom 2009), entrances of municipal wastes, washing and bathing with phosphate based detergents and soaps (Davies et al. 2009) as well as washing of cow dung's into the reservoir (Schmitz 1996; Mustapha 2008). This is an indication of the existence of pollution, and therefore bad for aquatic lives and highly exaggerated as compared to other standards, e.g., 0.005 to 0.020 mg/l PO_4-P (Chapman 1996); 0.01 to 0.03 mg/l PO_4-P (Schmitz 1996; Yajurveddi 2008). Silicate concentration was too high (22.5 mg/l), especially in main rainy season due the effects of runoff from the watershed (Little 2004), the presence of high rate of rock and soil weathering in the water body (Little 2004; Meesukko et al. 2007). This concentration is normal and satisfied freshwater ranges from 1-30mg/l (Chapman 1996) and therefore, it is good for growth of both aquatic organisms.

Biological Characteristics

Zooplankton Compositions and Abundances

A total 16 genera from 3 taxonomic groups (class) of zooplanktons were recorded. In littoral zone, pre-rainy season zooplankton was (73.77%) higher than other seasons due to the presence of conducive water temperature (Davies & Otene 2009; Ferdous & Muktair 2009; Scholl & Kiss 2009); and dry was (1.56 %) the least representative. The least percentage of dry season zooplankton in littoral zone could be influenced by water level reduction. Being this, zooplankton found in the littoral zone might migrate into the open zone since they are sensitive to changing physicochemical parameters. Because of this reason, high percentages of zooplanktons were recorded in open zone. Additionally, the blooming of Cyanophyceae at dry season exerts a negative influence on the feeding and development on zooplanktons abundances (Goldwyn & Kowalczewska-Madura 2007). In open zone, dry season zooplankton was (60.16%) higher than other seasons due to the presence of enough nutrients (Abowei et al. 2008) and phytoplankton genera (Chl-a= 15.65µg/l, Table 1), conducive temperature (24.2°C), and relatively less water level reduction respect to depth.

In both sites, rotifers were the dominant due to the ability of tolerate the unfavorable influences (Scholl & Kiss 2009) and they are an indication of eutrophic and turbid nature of the reservoirs. Dominance of rotifers across season was supported the presence of the predominance of Brachionus species, and occurrence of Keratella and Polyarthra spp (Matsumura-Tundisi et al. 1990). Generally, significance difference in zooplanktons genera were seen across season and sites due to the variation in limnological variables, and this is an indication the poor quality of the reservoir water.

Compositions and Abundances of Benthic Macro-invertebrate

Macro-invertebrates of 6 classes, representing 7 orders and 7 Families (Table 4) were identified in littoral zone. From all seasons, pre-rainy season (total absent) and main rainy season were poor in composition and abundance of macro-invertebrates. Poorness may be associated with the absence of immediate substrates for occupation and food availability (Dance & Hynes 1980). Besides, the accumulated of high sediment load, fluctuation of water level, and absence of enough food, and high concentration of NO_3-N (Bennett 1998) were additional reasons. From all orders, only Dipterans were found in three seasons due to having the ability of tolerate pollution and habitat disturbance (Iowa Watershed Monitoring and Assessment Program 2010), and ability to withstand lack of rich organic matter connected with inundation in rainy season (De Silva & Amarasinghe 2009).

Among all families, blooded red Chironomids was found in the three seasons due to the ability to live in all benthic zones (Iowa Watershed Monitoring and Assessment Program 2010), which is assisted by hemoglobin pigments at oxygen low environments. Also, the presence of Chironomidae only in main rainy season than the others families was due to having ability to withstand unfavorable substratum and lack of rich organic matter in connection with inundation (De Silva & Amarasinghe 2009). Bennett (1998) connected Chironomidae with elevated nitrate concentration in the reservoir due to organic pollution. This conclusion is agreed with the registered phosphate and nitrate concentrations and indicates the reservoir water pollution status.

Conclusion

Most of the physicochemical properties of Selameko reservoir were conducive for growth of aquatic organisms; however the high concentration of PO_4-P and to some extent NO_3-N indicated the presence of reservoir water pollution. This pollution confirmed by existence of pollution tolerant organisms, such as *Bosmina, Brachionus, Keratella* and *Polyarthra species,* and *Chironomidae*. Therefore; the reservoir is under anthropogenic pressure and both basin and reservoir management are recommended to solve such acute problems.

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Ethics

All the authors read and approved the manuscript and no ethical issues involved.

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