Effects of seasons and biotic factors on Zooplankton abundance in Jebel Aulia Reservoir, Sudan

John Leju CELESTINO LADU[1, 2]; Yatta S. LUKAW[3], Denis D. KENYI[4], Xiwu LU[1]

1. School of Energy and Environment, Dept. of Environmental Science and Engineering Southeast University, Nanjing 210096, P. R. China
2. College of Natural Resources and Environmental Studies. Dept. of Environmental Studies, University of Juba, South Sudan
3. College of Natural Resources and Environmental Studies, Department of Basic Sciences, University of Juba, South Sudan
4. College of Natural Resources and Environmental Studies, Department of Fisheries, University of Juba, South Sudan

John.leju6@gmail.com

Abstract: Effects of seasons and biotic factors on zooplankton abundance were investigated in Jebel Aulia reservoir from January 2003 to December 2003. Selected physical-chemical variables (water temperature, rainfall, sechi depth, water discharge, pH, dissolved oxygen, nitrate and phosphate) were measured at the time of zooplankton collection in dry and wet seasons respectively. Association of physicochemical variables with the zooplankton in the two seasons was statistically analyzed by Stepwise Linear Regression Test and all descriptive statistics done using SPSS version 9.5 for windows. Graphs were drawn using Microsoft Excel 2007. The correlation between the Crustaceans and Rotifers was deduced from a regression plot graph. Only water pH (both seasons), nitrate and dissolved oxygen concentrations were positively correlated with the zooplankton abundances in the dry season ($R>0.50$, $P<0.05$ and $P<0.01$). Crustacean abundance was positively correlated with the Rotifers ($R = 0.820$). The mean zooplankton abundance was high (75.33±29.75 cells L-1) in the wet season and low (40.67±14.58cells L-1) in the dry season. Crustacean made up 86.47% and 84.07%; Rotifers 13.52% and 15.93 of the zooplankton community composition in the dry and wet seasons respectively. Zooplankton community dominated by the Crustacean Cyclops which accounted for 38.93% and 33.85% in the dry and wet seasons respectively. The study confirmed that the abundance of the zooplankton in the study area was controlled by the physicochemical variables which varied greatly with seasons; highest zooplankton productivity occurred in the wet season.

[John Leju CELESTINO LADU; Yatta S. LUKAW, Denis D. KENYI, Xiwu LU. **Effects of seasons and biotic factors on Zooplankton abundance in Jebel Aulia Reservoir, Sudan.** Nature and Science 2012;10(5):113-119]. (ISSN: 1545-0740). http://www.sciencepub.net/nature. 13

Keywords: Zooplankton; physicochemical variables; Crustaceans; Rotifers; biotic factors

1. Introduction

The dominant zooplanktons in freshwater ecosystems are rotifers and microcrustaceans made up of cladocerans and copepods. Generally, zooplankton occupies a central position in the trophic link between primary producers and higher trophic levels; they are also good bio-indicators of the physical and chemical conditions of aquatic environments which cause changes in the qualitative and quantitative composition of zooplankton and influence their densities (Radwan 1973, 1976; Hillbricht-Ilkowska, 1977; Karabin, 1985; **Matveeva, 1991).**

Many workers investigated tropical zooplankton diversity, for example Qiu Qin et al, 2003, Rita Paez et al 2005, Archifa, M.S. 1984, Gillooly, et al 2000. From studies, they found that changes in physicochemical characteristics of any aquatic system can lead to qualitative and quantitative changes in the planktonic communities. Few workers carried out their investigations on the White Nile reservoir.

Jebel Aulia dam serves for flood control, water supply and the generation of hydroelectric power. Such physical modifications are known to have serious ecological impact on river organisms, especially fish and benthic fauna in rivers (Sinada, F.A et al 1984).

Plankton reservoir community represents an important resource of energy and matter flow in the reservoir food web and provides ways of predicting and increasing the productivity of a fresh- water system (Yoshimura C, et al 2005). Understanding the effects of seasons on zooplankton abundance will help in knowing when fish productivity is maximum and good for harvesting.

Systematic studies of the effects of wet and dry seasons on the zooplankton communities in the reservoir based on long-term sampling during the wet and dry seasons are needed, and such studies will contribute to our knowledge of seasonality in tropical reservoir such as Jebel Aulia.

The objective of this study was to examine how the wet and dry seasons influence the abundance of the zooplankton community in the reservoir and to know the season for maximum zooplankton abundance.

2. Material and Methods

2.1 Description of the Study Area

Jebel Aulia dam is situated 42 Km south of Khartoum (latitude of 15°N and longitude of 32°E). At its highest level, the reservoir covers an area of about 600 Km^2. Its width varies between 1 – 1.5 Km and has a maximum depth of 12.5m. There are series of seasonal drainage which drain into the reservoir from the eastern bank.

2.2 Sampling the Planktons

Samples were taken fortnightly for zooplanktons and physical factors and monthly for chemical factors. The study covers the period from January to December 2003. The zooplanktons were collected by towing plankton nylon net from a boat moving against the current for ten minutes. Five hauling were taken at two minutes interval; Contents were kept in a plastic bottle in capacity of a liter. Immediately 4% formalin was added and the sample was left to stand for 24 hours. When the suspension settled down, the supernatant water was siphoned off leaving sediment varying between 5 – 25 ml in volume, according to the richness of the catch. Ten slides from the sample were first thoroughly examined under the lower power of the microscope (×10) before counting it under the high power (×40). Five transects, selected at random, and from each slide the zooplanktons were examined under the high power. All the zooplanktons encountered in these transects were counted and identified to genera level using identification key. (Suarez-Morales et al 1993).

2.3 Water analysis for physical and chemical parameters

Water transparency was estimated by using a Secchi disc 40 cm in diameter and the results were expressed in Centimeters. Data on the amount of rainfall and water discharge during the study period were obtained from the Meteorological Department at Jebel Aulia.

Water for chemical analyses was collected from a depth of about 20 cm. The sample was filtered on the site immediately after collection through filter paper (Whatman GF/C No. 42), except water for pH and dissolved oxygen. The chemical analyses were completed on the same day of collection. Dissolved oxygen was determined using Winkler procedure and results were expressed as $MgO_2\ L^{-1}$ (Smith, GM, 1950). **PH** was measured on arrival to the laboratory using a digital pH meter (Huck).

2.4. Statistical analysis

The correlation between the zooplankton with the physicochemical variables was analyzed by Stepwise Linear Regression Test and all descriptive statistics done using SPSS version 9.5 for windows. The correlation between the Crustaceans and the Rotifers was deduced from a regression plot graph. All graphs in this study were drawn using Microsoft Excel Software for windows 2007.

3. Results

3.1. Environmental Conditions

Table 1 shows the distribution of the physical and chemical variables during the study. The means of water transparency, water discharge and rainfall in the water column were in the order, 71.00 ± 13.26cm and 46.67±20.27cm; 66.67±13.78 $X10^6m^3$ and 46.67 ± 21.67 $X10^6m^3$; 0.00 mm and 51.00 ±11.53mm in the dry and wet seasons respectively. On the other hand, the means pH, dissolved oxygen content, dissolved organic matter, phosphate concentration, and nitrate concentration were in the order 6.60±0.12µgl-$l^{-1}$and 7.60±0.12µgl-l-1; 7.50±0.21 mgO_2L^{-1}and7.60±0.31mgO_2L^{-1}; 326.67±17.64µgl-1 and 395.00±22.55 µgl-1; 3533.33±296.27 µgl-1and 7134.00±3961.02 µgl-1 in the dry and wet seasons respectively. The N: P ratios annual means were 10.80±0.56 and 19.39±11.79 in the wet and dry season respectively. All the environmental variables varied between the two seasons and only pH did not vary.

3.2. Seasonal changes in the plankton abundance

Table 2 shows the seasonal mean abundance of total zooplankton ind. L^{-1}. The means of total phytoplankton and zooplankton abundance were 40.67±1 4.58 and 75.33±29.75 ind. L^{-1} and 1130.73 ±3 37.52 and 1420.83±345.98 Cell L^{-1}in the dry and wet seasons respectively. The mean crustacean abundance in the dry and wet seasons were 35.17±10.70 and 63.33±25.89 ind. L^{-1} while the mean Rotifer abundance in dry and wet seasons were 5.50 ± 3.88 and 12.00 ± 3.97ind. L^{-1}respectively, whereas the mean Daphnia, Cyclops, Kartella and Branchiano abundance were 12.67±7.59 and 15.00± 4.19; 15.83 ± 2.13 and 25.50±10.40; 5.50±3.88 and 4.00±1.00; 0.00 and 8.00 ± 4.77 ind. L^{-1} in the dry and wet season respectively.

Table (1) physicochemical variables (January- December 2003)

Variables	Mean ± SE	
	Dry season	Wet season
Transparency (cm)	71.00 ± 13.26	46.67±20.27
Rainfall (mm)	0.00	51.00 ±11.53
Water discharge (106m3)	66.67±13.78	46.67 ± 21.67
pH (µgl-l-1)	7.60±0.12	7.60±0.12
Dissolved oxygen (mgO2L-1)	7.50±0.21	7.60±0.31
Phosphate (µgl-1)	326.67±17.64	395.00±22.55
Nitrate (µgl-1)	3533.33±296.27	7134.00±3961.02

SE= Standard Error of the Mean. All the means shown above were calculated out of 12 months (the actual duration of the study).

Table (2) Seasonal changes in the plankton abundance

Category	Dry season	Wet season
	M ± SE	M ± SE
Total Phytoplankton(Cell L^{-1})	1130.73±337.52	1420.83±345.98
Total Zooplankton(ind. L^{-1})	40.67±14.58	75.33±29.75
Total Crustaceans(ind. L^{-1})	35.17±10.70	63.33±25.89
Total Rotifers(ind. L^{-1})	5.50 ± 3.88	12.00 ± 3.97
Daphnia(ind. L^{-1})	12.67±7.59	15.00± 4.19
Cyclops(ind. L^{-1})	15.83 ± 2.13	25.50±10.40
Kartella(ind. L^{-1})	5.50±3.88	4.00±1.00
Branchiano(ind. L^{-1})	0.00	8.00 ± 4.77

SE = Standard Error of the Mean.

3.3. Seasonal changes and zooplankton abundance

Figures 1 explains the fluctuation of the plankton (Zooplankton and phytoplankton) during the study. In April the phytoplankton density was high and it dropped to its minimum density of 497cells L^{-1} in June. The phytoplankton density started to rise through July, August and peaked up in September (wet season) with a density of 1950 cells L^{-1}. The zooplankton density on the other hand, dropped from 69 ind. L^{-1} in April to its minimum density of 20.5 ind. L^{-1} in May (dry season). It then rose up through June and shot up once to attain its highest density at 122 ind.L^{-1} in July. In wet season, it then started to drop through August and finally its density dropped to 23 ind. L^{-1} in September at the same time that the phytoplankton was shooting up to its highest density. It is also clear from the figure that both population density drop from April to May then both rose up again through June to July. However, from July, the phytoplankton density continued to increase until it attained its maximum peal in September, while the zooplankton population, after attaining its maximum peak in June declined through August and finally dropped to low density in September.

3.4. Composition of the zooplankton community

During the study period (as shown in figure 2) Daphnia made up 31.15 %, Cyclops 38.93%, Nauplii 16.39%, Kartella 13.53% and Branchiano made up 0.00% of the total zooplankton encountered in the dry season. Whereas in the wet season Daphnia, Cyclops, Nauplii, Kartella and Branchiano accounted for 19.91%,33.85%,30.31%, 5.31% and 16.62% respectively of the total zooplankton proportion. In both seasons, on the other hand, Daphnia made up 51.06%, Cyclops72.78%, Nauplii 46.70%, Kartella 18.84% and Branchiano 10.62%. Looking at zooplankton composition at the class level, Crustaceans and Rotifers accounted for 86.47% and 13.53% respectively in the dry season and 84.07% and 15.93% respectively in the Wet season. Examining the population density, it is clear from figure 3 that the highest density in the dry season was 47.5 ind.L^{-1} attained by Cyclops followed by Daphnia 38 ind.L^{-1}, Nauplii 20 ind.L^{-1},Kartella 16.5 ind.L^{-1} then Branchiano with a density of 0 ind.L^{-1}. In wet season on the other hand, the highest density was 76.5 ind.L^{-1}) reached by Cyclops followed by Nauplii 68.5 ind.L^{-1},Daphnia 45 ind.L^{-1}, Brachiano 12 ind.L^{-1} then Kartella which had the lowest density of 12 ind.L^{-1} in the wet season.

It is apparent that the zooplankton community was dominated by the Crustaceans in both the dry and the wet season due to Cyclops which greatly contributed for the highest density of 124 ind. L^{-1} in both seasons.

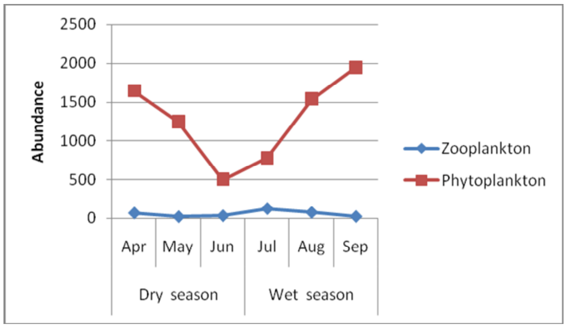

Figure 1. Fluctuation of plankton with seasons

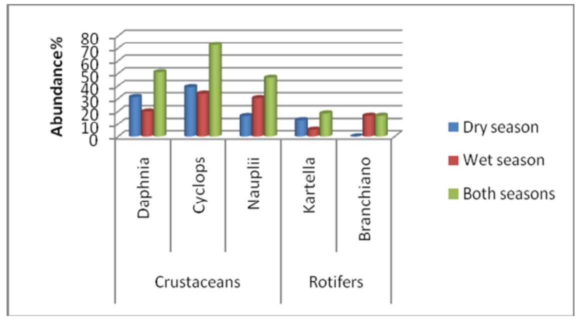

Figure 2. Composition of the major zooplankton genera

Table (3) Correlation between Zooplankton and physicochemical variables

		Variables			
Category	Season	Mean	Max	Min	R
W.trans(cm)	Dry	66.8	88.5	45	R=-0.50
	Wet	55	87	23	R=-0.50
Rain(mm)	Dry	74.5	94	55	R =1.00* *
	Wet	46	64	28	R =-1.00**
WD(106m3)	Dry	53	56	50	R =1.00**
	Wet	67	80	54	R =-1.00**
pH(µgl-l-1)	Dry	7.6	7.8	7.4	R=-1.00**
	Wet	7.6	7.8	7.4	R=1.00**
PO43-(µgl-1)	Dry	330	360	300	R=1.00**
	Wet	382.5	415	350	R=-1.00**
NO32- (µgl-1)	Dry	3600	4100	3100	R=1.00**
	Wet	8701	15002	2400	R=-1.00**
DO(mgl-1)	Dry	7.55	7.9	7.2	R=1.00**
	Wet	7.5	8	7	R=1.00**
DOM(mgO2l-1)	Dry	21.2	16.8	25.6	R=-1.00**
	Wet	14.15	16.3	12	R=1.00**

*Significant (P<0.05); ** highly significant (P<0.01); ^{NS} Non significant (P>0.05); Max, maximum; Min, minimum; W.trans, water transparency; W.D, water discharge; DO, dissolved oxygen; DOM, dissolved organic matter.

3.5. Association of Zooplankton with physicochemical variables

Table 3 shows the association of the physicochemical variables with the zooplankton densities. From table 3, zooplankton showed positively high significant correlation (R=-1, P<0.01) rain and water discharge in the dry season. However, the zooplankton exhibited negative correlation (R=-0.50, P<0.05) with water transparency in both seasons; significantly negative correlation (R=-1, P<0.01) with rain and water discharge in wet seasons.

It is also conspicuous from the table that the zooplankton highly exhibited significant positive correlation (R = 1.00, P <0.01) with water pH, nitrate concentration and dissolved organic concentration in the dry season. Whereas it exhibited highly significant positive correlation (R = 1.00, P <0.01) with dissolved oxygen in the dry season and with dissolved organic matter concentration in the dry and wet seasons.

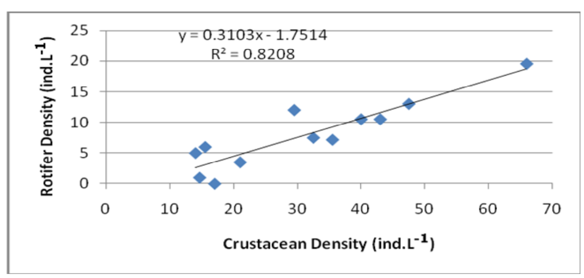

Figure 3. Correlation between Crustaceans and Rotifers

3.6. Biotic interaction between Crustaceans and Rotifers

Figure 3 shows the correlation between Crustaceans and Rotifers. It is apparent from the figure that there was a high significant correlation between the Crustaceans and Rotifers density

(R^2=0.820) in both seasons. From the figure, the Crustaceans density increases as Rotifers population density shoots up.

4. Discussion

4.1. Physicochemical data

The data on the temperature, rainfall, water discharge, secchi transparency, pH range, phosphate, nitrate, dissolved oxygen and dissolved organic matter values, general were in agreement with limnological characteristics of the Nile water and did not change from the one measured by Rzoska, J. and Talling, J.F. (1967) since 48 years ago. The pH of the water was found to be fairly alkaline, since its mean hydrogen ion concentration was 7.60±0.12 in both the dry and the wet seasons. This indicates that the White Nile is capable of preventing abrupt changes in the pH due to its high buffering capacity (Sinada, F.A. and Karim, A.G. 1984).

4.2. Abundance and seasonality

The zooplankton community showed variations in density as a function of physicochemical variables and seasons. Higher water discharge and lower abundances were recorded in the dry season, while lower water discharge and higher zooplankton abundances recorded in the wet season. At the higher discharge, the zooplankton cannot maintain their position and were therefore drifted down stream leading to the lower abundance. As the discharge was lower in the wet season than in the dry season the abundance in the wet season was higher than in the dry season. This result was in agreement with the previous findings of Rzoska, J. and Talling, J.F. (1967), Mackereth, F.J.H. (1963), Sandlund, OT. (1982) and Basu BK, Pick, FR. (1996).

Rain is an important factor that imports nitrates into the system (Prowse, G.A. and Talling J.F. 1959, Talling, J.E and Lemoalle, J. 1998. By looking at the nitrate content in the wet season, it was higher than in the dry season. In the dry season there was no correlation between the zooplankton and nitrate content of the reservoir. As there was no rainfall to be recorded in the dry season and therefore nitrate input into the system was low. In the wet season, however, was nitrate concentration had influence on zooplankton abundance. This higher nitrate concentration (eutrophication) in the wet season resulted in higher abundance of phytoplankton that in turn supported the zooplankton leading to the same result confirmed by Nohueira, M.G., Henry, R., Maricatto, F.E. (1986). Therefore, rain intensity is an important factor in regulating the densities of the zooplankton (Roldan, G., Ruiz, E. 2001, Lavans, B. and Sorgeloos, B. 1996).

The stepwise regression result (table3) showed that pH influenced the zooplankton abundance in the dry season. The least zooplankton abundance that occurred in May was observed at the pH 7.2. This pH level is lower than mean pH (6.60 ± 0.12) measured in the dry season. Though the pH range in the dry season was favorable for the zooplankton development, however, it was not suitable for phytoplankton growth. Algae grow at a pH optimum range between 8.2 – 8.7 (Bays, J.S., Crisman, T.L. 1983). The study, however, obtained an optimum pH range which is less than the one specified above in both the dry and the wet seasons and might have contributed to low phytoplankton abundance in May and indirectly affected the zooplankton abundance in the dry season. However, on the other hand, the pH (8) measured during the highest zooplankton abundance in July (wet season) was within the mean pH optimum. According to Subra et al. (2007) the optimum pH rang for Rotifers is (6.9-8.6).

Phosphate and nitrate concentrations appeared to influence zooplankton abundance. This suggested that the highest zooplankton population was due to the eutrophication caused by the high nitrate concentration which corresponded with the phytoplankton maximum abundance in this period.

Factors such as food and predation usually control temporal and special distribution of the zooplankton community (Chang KH, Nagata T, Hanazato T. 2004, Admiraal, and W.1991). The study noticed that the population of the zooplankton was always below the phytoplankton throughout the two seasons (Fig1). For Rotifers to reach a grazing level their numbers should be in the range (>600-to approximate 1600 ind. L^{-1}) in order to reach a high grazing rates of (7-32% day -1), a finding that was confirmed by [34]. However, the result found that throughout the study period the mean Rotifer density were 5.50 ± 3.88 and 12.00 ± 3.97 ind. L^{-1} in the dry and wet seasons respectively. It is therefore clear that these densities did not reach grazing level to negatively influence the phytoplankton population. By looking at the total zooplankton mean abundance in the dry (40.67±14.58 ind. L^{-1}) and wet (75.33±29.75 ind. L^{-1}) seasons one might conclude that the zooplankton had minor effect on the phytoplankton abundance during the study since the zooplankton community did not attain a grazing level with significant effect on the phytoplankton abundance during the study period.

Generally, possible interactions between phyto- and zooplankton in rivers have mostly been discussed empirically or estimated from zooplankton abundance and literature data on filtration activities of various taxa (Gosselain, V., Descy, J.-R & Everbecq, E. 1994, Demott, W.R. (1989).

However, when the crustacean density was plotted against the rotifer density (Fig 3), no significant inverse relation existed, showing evidence for the absence of strong suppressive abilities of the crustaceans over rotifers in the Reservoir. This might be attributed to the availability of food (phytoplankton) at level that is not limiting especially in a eutrophic (N: P>1) reservoir such as Jebel Aulia and therefore reduces competition or predatory interaction between the two zooplankton (Crustaceans and Rotifers). The same finding was confirmed by Demott, W.R. et al. (1989) who found out that in the abundance of food resources the competitive or predatory relationships among the zooplankton becomes minimum or even reduced.

Throughout the study period the dominant zooplankton was the Crustacean Cyclops which dominated over the total zooplankton community in both the dry and wet seasons respectively. Tropical oligotrophic systems are dominated by copepods (Crustaceans), whereas more eutrophic systems are dominated by rotifers and cladocerans. However, the domination of the zooplankton by the Cyclops is not a surprising finding; other workers obtained the same results, for example Rita Paez et al. (2005), found that cladocerans and cyclopoid (Crustacea) are associated to the more eutrophic lakes and reservoirs, which support greater crustacean abundances in most latitudes. Rotifer abundance was lower than the abundance of Crustaceans in the reservoir throughout the study period. In eutrophic environments, where food is a limiting factor, the number of rotifer species decreases, while the density increases. However, the result of this present study did not agree with the finding of the above author; it found two rotifer species (Kartella and Branchiano) and both species showed the least abundance compared to the Crustaceans. This might be due to the reason that food is not a limiting factor in Jebel Aulia Reservoir as the N: P>1 which might suggest that there would always be abundant phytoplankton to sustain the zooplankton communities.

5. Conclusion

Zooplankton seasonal abundance is influenced by the seasons and change in physicochemical characteristics. Change in physicochemical characteristics in any aquatic system can lead to qualitative and quantitative changes in the planktonic communities. Changes in the physicochemical variables varied from one season to another and therefore the zooplankton abundance varied accordingly. Maximum zooplankton abundance occurred in the wet season, while the minimum abundance occurred in the dry season. Zooplankton densities in the reservoir did not reach a grazing level and therefore had minor effects on the phytoplankton abundance.

Acknowledgements

Sincere gratitude goes to College of Natural Resources and Environmental Studies, University of Juba for providing academic support. Acknowledgment is extended to Late. Associate Prof. Marcelino Tombe Jada, Associate Prof. James Oriho Ahasa and all the entire staffs of University of Juba.

Corresponding Author:
John Leju CELESTINO LADU.
School of Energy and Environment, Dept. of Environmental Science and Engineering Southeast University, Nanjing 210096, P. R. China
E-mail: john.leju6@gmail.com.com

References

1. Archifa, M.S. (1984). Zooplankton composition of ten reservoirs in southern Brazil. Hydrobiologia, 1984. 113, 137–145.
2. Dussart, B.H., Fernando, C.H., Matsumura-Tundisi, T., Shiel, R.J. (1984). A review of systematics, distribution and ecology of tropical Fresh water zooplankton. Hydrobiologia, 113: 77–91.
3. Lewis, W.M. (1987). Tropical limnology. Ann. Rev. Ecol. Systemat, 18: 159–184.
4. Dumont, H.J. (1994. On the diversity of the Cladocera in the tropics. Hydrobiologia, 272: 27–38.
5. Gillooly, J.F., Dodson, S.I . (2000). Latitudinal patterns in the size distribution and seasonal dynamics of new world, freshwater cladocerans. Limnol. Oceanogr. 45: 22–30.
6. Lin, Qiu.-Qi., Duan, S.-S., HU, R., Han, B.-P. (2003). Zooplankton distribution in tropical reservoirs, South China. Int. Rev. Hydrobiol., 88, 602–613.
7. Moss B. (1988). Ecology of Freshwaters: Man and Medium, second editon. Blackwel Scientific Publications London, 417 pp.
8. Mohammed, AA and Fathi AA. (1990). The condition of the Nile in the years 1986–1987 at El-Minia, Egypt. Bull Sci Assiut Univ, 19 (1-D): 141–164.
9. Fathi, AA and El-Shahed AM. (1998). Response of Nile water Phytoplankton to some heavy metals and their interaction with carbonate and EDTA. J Union Arab Biol Cairo, Botany, 6: 1–12.
10. Rzoska, J. and Talling, J.F. (1967). The development of plankton in relation to Hydrological regime in Blue Nile, University of Khartoum, Hydrobiological Research Unit, 645 – 646.
11. Prowse, G.A. and Talling J.F. (1959) The Seasonal growth and succession of plankton algae in the White Nile. Limnol. Oceanogr, 3:22 – 236.

12. Talling, J.E and Lemoalle, J. (1998). Ecological dynamics of tropical inland waters. Cambridge.
13. Sinada, F.A. and Karim, A.G. (1984). Physical and Chemical Characteristics of the Blue and White Nile at Khartoum. Hydrobiologia, Vol. 110: 27 – 29.
14. Yoshimura C, Omura T, Furumai H, Tockner K. (2005). Present state of rivers and streams in Japan. River Res Appl.,: 21:93–112.
15. Bonecker, C.C., Nagae, M.Y., Bletller, M.C.M., Velho, L.F.M., Lansac-Toha, F.A. (2007). Zooplankton biomass in tropical reservoirs in southern Brazil. Hydrobiologia, 579: 115–123.
16. Suarez-Morales, E., Va´squez-Mazy, A., Solis, E. (1993). The zooplankton community of a Mexican eutrophic reservoir, a seasonal survey. Hidrobiologica, 3:71–80.
17. Smith, GM. (1950). The Fresh Water Algae of the United States, second edition, New York, McGraw-Hill, pp 719.
18. Mackereth, F.J.H. (1963). Water Analysis, Some Revised Methods for Limnologists. Scientific Publications of the Freshwater Biological Association, U.K., No. 36.
19. Sandlund, OT. (1982). The drift of zooplankton and microzoobenthos in the river Strandaelva, western Norway. Hydrobiologia, 94:33–48.
20. Basu BK, Pick, FR. (1996). Factors regulating phytoplankton and zooplankton biomass in temperate rivers. Limnol Oceanogr, 41:1572–1577.
21. Campbell, CE. (2002). Rainfall events and downstream drift of microcrustacean zooplankton in a Newfoundland boreal stream. Can J Zool, 80:997–1003.
22. Biswas, S. (1968). Hydrobiology of the Volta River and some of its Tributaries before the formation of Volta Lake, Ghana J.Sci.,: 8: 152 – 166.
23.] Nohueira, M.G., Henry, R., Maricatto, F.E. (1986). Spatial and temporal heterogeneity in the Jurumirim Reservoir, Sao Paulo, Brazil. Lakes Reservoirs: Res. Manage ,1999: 4: 107–120.
24. Roldan, G., Ruiz, E. (2001). Development of Limnology in Colombia. In: Wetzel, R.G., Gopal, B. (Eds.), Limnology in Developing Countries. Int. Assoc. Limnol.(SIL), pp. 69–119.
25. Lavans, B. and Sorgeloos. B. (1996). Manual on the production and use of live food for aquaculture. FAO Fisheries Tech paper.
26. Bays, J.S., Crisman, T.L. (1983). Zooplankton and trophic state relationships in Florida lakes. Can. J. Fish. Aquat. Sci., 40, 1813–1819.
27. Duggan, I.C., Green, J.D., Shiel, R.J. (2001). Distribution of rotifers in North Island, New Zealand, and their potential use as bioindicators of lake trophic state. Hydrobiologia, 446–447, 155–164.
28. Auer, B., Elzer, U., Arndt, H. (2004). Comparison of pelagic food webs in lakes along a trophic gradient and with seasonal aspects: influence of resource and predation. J. Plankton Res, 26, 397–709.
29. Castro, B.B., Antunes, S.C., Pereira, R., Soares, A.M., Gonc-alves, F. (2005). Rotifer community structure in three shallow lakes: Seasonal fluctuations and explanatory factors. Hydrobiologia, 543:221–232.
30. Brandl, Z. (2005). Fresh water copepods and rotifers: predators and their prey. Hydrobiologia, 546: 475–489.
31. Hassett RP, Cardinale B, Stabler L.B, Elser JJ. (1997). Ecological stoichiometry of N and P in pelagic ecosystems: comparison of lakes and oceans with emphasis on the zooplankton-phytoplankton interaction. Limnol Oceanogr, 42:648–662.
32. Chang KH, Nagata T, Hanazato T. (2004). Direct and indirect impacts of predation by fish on the zooplankton community: an experimental analysis using tanks. Limnology, 5:121–124.
33. Admiraal, W., Van Zanten, B. & De Ruyter Van, E. D. (1991). Biological and chemical processes in communities of bacteria, phytoplankton and zooplankton in the lower river Rhine. In: KINZELBACH, R. & FRIEDRICH, G. (eds.), Biologic des Rheins, Limnologie aktuell, New York, Stuttgart, pp. 151-i60.
34. Gosselain, V., Descy, J.-R & Everbecq, E. (1994). The phytoplankton Community of the River Meuse, Belgium: seasonal dynamics and the possible incidence of zooplankton grazing. Hydrobiologia, 289: 179-191.
35. Demott, W.R. (1989). The role of competition in zooplankton succession. In: Sommer, U. (Ed.), Plankton Ecology: Succession in Plankton Communities. New York, Springer, pp. 195–252.
36. Cecilia Enrıquez Garcia, S. NANDINI, S.S.S. SARMA. (2009). Seasonal dynamics of zooplankton in Lake Huetzalin, Xochimilco (Mexico City, Mexico). Limnologica, 39 : 283–291.
37. Demott, W.R. (1989). Horizontal and seasonal patterns of tropical zooplankton from the eutrophic Prado Reservoir (Colombia). Limnologica, 39, 128–139.
38. Pinto-Coelho, R., Pinel-Alloul, B., Methot, G., Havens, K.E., (2005). Crustacean zooplankton in lakes and reservoirs of temperate and tropical regions: variation with trophic status. Can.J.Fish. Aquat.Sci. 62: 348–361.
39. Rita Paez et al. (2005). Limnological studies on a shallow reservoir in western Venezuela (Tulé Reservoir)
40. Hillbricht-Ilkowska, A. (1977) Trophic relations and energy flow in pelagic plankton. Pol. Ecol. Stud. 3(1), 3-98.
41. Karabin, A. (1985). Pelagic zooplankton (Rotatoria + Crustacea) variation in the process of lake eutrophication. I. Structural and quantitative features. Ekol. Pol. 33(4), 567-616.
42. Matveeva, L. K. (1991). Planktonic rotifers as indicators of trophy. Bjull. Mosk. Obšc. Isp. Prir., Otd.

4/4/2012