VARIATIONS IN ZOOPLANKTON DIVERSITY AND ABUNDANCE IN FIVE RESEARCH FISH PONDS IN NORTHWEST AMHARA REGION, ETHIOPIA

[1] **Akoma, O. C.*, [2]Goshu, G. and [3]Imoobe, T. O. T.**
[1] Department of Biology, Bahir Dar University, Ethiopia.
[2] Amhara Regional Agricultural Research Institute, P. O. Box 527, Bahirdar, Ethiopia gorawha@yahoo.com
[3] Department of Animal and Environmental Biology, University of Benin, Nigeria timoobe@yahoo.co.uk
*Corresponding author's email: osonduakoma@yahoo.com
(Received: January, 2014; Accepted: February, 2014)

ABSTRACT

Zooplankton diversity, abundance and some selected environmental parameters of water quality were monitored in five aquaculture research ponds between December 2007 and June 2008 in North West Amhara region of Ethiopia. Bichena-I and Bichena-II fish ponds which received sub-surface water showed significantly lower ($P \leq 0.05$) values of temperature and turbidity than the surface water-sourced ponds. In contrast, Amanuel, Yewela and Gozamen fish ponds that received surface water showed lower values of total hardness, conductivity, total dissolved solids, nitrate and ammonia than Bichera 1 and 11 ponds. Zooplankton diversity was determined using Margalef's index of species richness(S), Shannon–Wiener diversity index(H) and Evenness Index (E) while correlation coefficient values were used to determine the relationship of zooplankton diversity and the environmental parameters considered. The zooplankton fauna consisted of 52 species comprising 19 species of rotifers (Rotifera), 18 species of copepods (Copepoda) and 15 species of cladocerans (Cladocera). The values of all the three measures of diversity considered (S, H_1 and E) all pointed to the fact that the fish ponds that received surface water were characterised by high zooplankton diversity than those that received subsurface water source. Margalef species richness (S) and Shanon-Wiener's index (H') were both highest in Yewela fish pond and lowest in the turbid Gozamen fish pond. The highest value of evenness index (E) was recorded for the Amanuel fish pond while the lowest value was in Bichena-I fish pond. The study indicated that the fish ponds replenished with water sourced from surface water bodies showed higher zooplankton diversity than those of the subsurface water sourced ponds thereby suggesting preference for surface water source as better option for achieving optimal feeding conditions for managing fish ponds in the locality.

Key Words: Copepoda, Cladocera, Rotifera, Species Richness, Surface, Sub-surface Water

INTRODUCTION

Although there are many similarities among aquatic ecosystems, every aquatic ecosystem is unique in some respects and hence different from the others. Fish is an inexpensive source of protein and an important trade commodity in many regions of world and water is the physical support in which they carry out their life functions such as feeding, swimming, breeding, digestion and excretion (Bronmark and Hansson, 2005). A fish pond is a controlled environment stocked with edible fish species for aquacultural, research or commercial purpose. It provides unique conditions for plankton growth, especially zooplankton with the abiotic environmental factors and other characteristics forming specific microhabitats that influence development and growth of fish. Dynamic throughput of nutrients and material budget of ponds are determined to a large extent by the source of inlet waters and interactions between both biotic and abiotic conditions in and around the pond. Optimum fish production is totally dependent on the physical, chemical and biological qualities of water to most of the extent (Bhatnagar and Devi, 2013).

Zooplankton constitute important food item of many omnivorous and carnivorous fishes and also play important role in the food chain as they are in the second trophic level as primary consumer and also as contributors to the next trophic level (Rahman and Hsaain, 2008). The zooplankton community is a dynamic system that responds promptly to environmental changes. The relationship between the physico-chemical parameters of water quality and plankton production in fish ponds is of great importance and essential for fish culture (Islam, 2007). Water quality in fish ponds is often due to the interactions of several physico-chemical components and can have profound effects on pond productivity, the level of health and fish health. Because of the vital role zooplankton play in the food chain of fish ponds, both the zooplankton species composition and their abundance are important in successful management of aquaculture (Boyd, 1982).

Our knowledge of the consumption of plankton by fish is still fragmentary. Trophic links between fish and plankton are often loose because plankton is a changing assemblage of pelagic organisms of valuable nutritional value (Ikpi *et al.*, 2013). In the present study information was obtained on the zooplankton abundance species diversity, and selected water quality parameters. The objectives of the study were to determine the distribution and diversity of zooplankton in five research fish ponds receiving water from surface water and underground water sources with a view to determining the best environmental conditions for optimal food conditions for the young fish in the ponds. This is to provide information on the most suitable water supply option for the experimental ponds for effective and sustainable utilization of fisheries resource in North-West Amhara region, Ethiopia.

Study Area

Five on-farm research fish ponds in the East Gojjam administrative zone, Northwest Amhara region, Ethiopia were studied. Three of the ponds namely Amanuel, Yewela and Gozamen received water supply from surface water (stream) and the remaining two ponds namely Bichena-I and Bichena-II received subterranean (well) sourced water. Morphometric, and environmental data on the ponds are given in Table 1.

Table 1: Morphometric Characteristics of the Five Study Ponds

Pond	Pond Abbrev.	GPS Readings	Altitude (masl)	Area (m^2)	Mean Depth (m)
Yewela	Y2	10 ° 23'N 37 ° 34'E	2173	100	1.5
Gozamen	Y1	10 ° 22N 37 ° 36'E	2227	100	1.5
Amanuel	A0	10 ° 26' N 37 ° 32' E	2272	100	1.5
Bichena II	B2	10 ° 25'N 38 °16' E	2388	100	3.0
Bichena-I	B1	10°25'N 38 ° 16'E	2402	144	3.0

All of the study ponds were stocked with Nile Tilapia, *Orechromis niloticus,* and only Gozamen fish pond was additionally stocked with Common Carp, *Cyprinus carpio*. The ponds were stocked at a density of two fingerlings per square meter pond surface area. The surface-water-sourced ponds were characterized by laterite soil and the sub-surface water sourced ones have vertisoil. The ponds were part of a pilot project by the Amhara Regional Agricultural Research Institute (ARARI) fisheries production project. The fishermen fertilize the water with compost approximately every two weeks just after the water is replenished by putting approximately 20 kg of compost mainly prepared from cow dung and locally-available leafy plants excluding leaves of Eucalyptus leaves (because of their hard texture and difficulty in comminution) in a sack, tied and kept submersed in a corner of the pond where essential nutrients leach from the compost into the water column.

The ponds are primarily devoted to fish production but have also been used as water storage reservoir for irrigation.

MATERIALS AND METHODS

Sampling and Analysis

Zooplankton sampling was done at intervals of two months from December 2007 to June 2008 to cover both the dry and wet seasons. Twenty liters of water samples were collected at each of the fish ponds with a bucket and then sieved through an 80μm mesh plankton net and immediately fixed in few drops of 4% formaldehyde solution. Observation and identification of zooplankton to species level was done under a microscope. Classification was with the aid of relevant literature (Korinek, 1999; Smirnov, 1996; Defaye, 1988; Van de Velde, 1984). Each concentrate sample was further sub-sampled (1:10), and all individuals of each species present were counted.

Basic statistical measurements of diversity indices were used to describe the zooplankton community structure. The three indices of species diversity used: The Shannon–Wiener diversity Index,(H_1) Evenness Index (E) and Margalef Index of species richness (S) were estimated using the computer BASIC programme SPDIVERS.BAS (Ludwig & Reynolds, 1988) which provide a tool for monitoring temporal and spatial changes. Differences in zooplankton diversity among the ponds were determined using one-way Analysis of Variance (ANOVA).

Water samples were collected for physico-chemical analyses. Electrical Conductivity, pH, dissolved oxygen, temperature and total dissolved solids were measured *in-situ* with probes. Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were measured with EC/TDS meter (Hanna, Model Hl 98312) and dissolved oxygen with meter (Model OXi 315 i), WTW82362).

Total hardness, ammonia, nitrite, nitrates and chloride were determined colometrically using Palintest analytical kit (Palintest Ltd, Newcastle upon Tyne, UK) in accordance with the manufacturer instruction (Palintest transmittance-display photometer 5000). Aliquots of water samples were collected and filtered through 0.45μm pore size, 47mm diameter Glass fibre filters. Samples with expected high concentrations of the respective chemicals were diluted so that they could be measured within the linear detectable range.

RESULTS

Water Physico-chemical Parameters

A summary of the data obtained on the investigated physico-chemical parameters of water quality in the ponds is presented in Table 2. The mean temperature, turbidity, chloride, dissolved oxygen, pH and nitrite values were relatively higher in the pond water sourced from surface water body than the pond water sourced from subsurface water body. These subsurface sourced pond waters however had higher mean values of conductivity, total hardness, nitrate and ammonia than the surface sourced water ponds with the conductivity and total hardness values significantly higher (Mann Whitney, $P < 0.05$, n = 8).

Table 2. Physico-chemical Characteristics of the Fish Ponds

	Subsurface Water Source						Surface Water Source					
Parameter	n	Min	Max	Mean	Std. Error	P-value	n	Min	Max	Mean	Std. Error	P-value
T(°C)	4	18.3	24.9	21.46	0.99	<0.05	4	17.00	26.60	22.64	1.02	>0.001
Turbidity (NTU)	4	23	80	39.88	6.73	<0.05	4	29.00	401.00	109.00	46.03	>0.001
Cond. (μScm^{-1})	4	457	590	536.25	17.17	>0.001	4	40.00	158.00	105.00	15.13	>0.05
TH (mgL^{-1} $CaCO_3$)	4	265	465	356.88	23.11	>0.001	4	70.00	195.00	116.25	12.98	>0.05
Cl (mgL^{-1})	4	20	48	38.12	3.29	>0.001	4	10.00	87.00	45.63	11.93	>0.05
DO (mgL^{-1})	4	4.6	7.6	5.86	0.35	>0.001	4	4.70	9.60	7.21	0.51	>0.05
DO %	4	50	86	67.75	4.49	>0.001	4	58.00	132.00	90.38	8.44	>0.05
pH	4	7.0	8.2	7.77	0.14	>0.001	4	6.90	8.40	7.80	0.21	>0.05
NO_3 (mgL^{-1})	4	0.08	4.40	2.14	0.504	>0.001	4	0.97	3.96	1.54	0.35	>0.001
NO_2 (mgL^{-1})	4	0.063	0.112	0.091	0.005	>0.001	4	0.023	0.317	0.109	0.032	>0.001
NH_3 (mgL^{-1})	4	0	12	2.25	1.45	>0.001	4	0	10.00	1.52	1.16	>0.001
TDS (mgL^{-1})	4	0.24	0.30	0.26	0.14	>0.001	4	0.02	0.06	0.037	0.0085	>0.001

Zooplankton Diversity

The recorded zooplanktonic organisms were rotifers, copepods and cladocerans. A total of 52 species (Table 3) in 12 families of six Orders were identified. Rotifera was the most represented group with 19 species while Copepoda and Cladocera consisted of 18 and 15 species respectively. The pond with greatest species richness(S) was the surface water sourced Yewela fish pond with a total species number of 31 and Margalef's species richness index (D) of 4.8289. The pond with least diversity in terms of species richness(S) and Margalef's species richness index (D) was Gozamen fish pond, another surface water sourced fish pond. The Shanon-weiner's index of diversity (H') was again highest in Yewela fish pond (2.9789) and lowest in Gozamen fish pond (2.3690).The highest evenness index was observed in Amanuel and lowest in Bichena-II (Figure 1). There was however no significant difference (P>0.05) in the diversity of zooplankton in the two categories of ponds.

Table 3: Species Composition of Zooplankton in the Five Research Fish Ponds

CLADOCERA	**COPEPODA**	**ROTIFERA**
Alona quadrangularis (2,3,4)	*Bryocamptus birsteini (1,3)*	*Brachionus angularis (1,2)*
Bosmina longirostris (1,2,4,5)	*Bryocamptus minutus (1)*	*Brachionus calyciflorus (3,5)*
Chydorus eurynotus (1,2,3)	*Ectocyclops phaleratus (3)*	*Brachionus falcatus (1)*
Chydorus reticulatus (5)	*Eucyclops agiloides (1,3)*	*Brachionus leydigi (1,3,5)*
Chydorus sphaericus (1,3)	*Eucyclops macrurus (1,3,5)*	*Brachionus patulus (4,5)*
Diaphanosoma excisum (1)	*Eucyclops serrulatus (2)*	*Brachionus quadridentatus (1,2,4,5)*
Echinisca capensis (1)	*Eucyclops speratus (1,3)*	*Brachionus urceolaris (1,2,3,4,5)*
Echinisca rosea (1,3)	*Eudiaptomus gracilis (2)*	*Filinia longiseta (2)*
Echinisca triserialis (1,3,5)	*Mesocyclops aequatorialis (1,3)*	*Keratella cochlearis (2,3,4)*
Macrothrix geoldi (5)	*Mesocyclops bodanicola (1,2,4,5)*	*Keratella quadrata (2,4,5)*
Macrothrix laticornis (5)	*Mesocyclops ogunnus (1)*	*Keratella tropica (3,4)*
Macrothrix spinosa (5)	*Microcyclops rubellus (3,4)*	*Keratella valga (1,3,4,5)*
Moina micrura (1,3,5)	*Microcyclops varicans (1,2,3,4,5)*	*Lecane bulla (4,5)*
Pleuroxus hamatus (5)	*Thermocyclops crassus (1,3,4)*	*Lecane papuana (4)*
Pseudocydorus globosus (2,3,4)	*Thermocyclops ethiopiensis (1,2,3,4,5)*	*Trichocerca cylindrica (1,4)*
	Thermocyclops hyalinus (1)	*Trichocerca elongata (4,5)*
	Thermocyclops neglectus (1,3,4)	*Trichocerca iernis (1,4)*
	Thermocyclops oithonoides (1)	*Trichocerca longiseta (1,2)*
	Copepodite larvae (4,5)	*Trichocerca similis (2)*
	Nauplius larvae (1,2,3,4,5)	

Numbers in parentheses represent the fish ponds where they occurred.
1= Yewela, 2= Gozamen, 3 = Amanuel, 4 = Bichena-1, 5 = Bichena-2

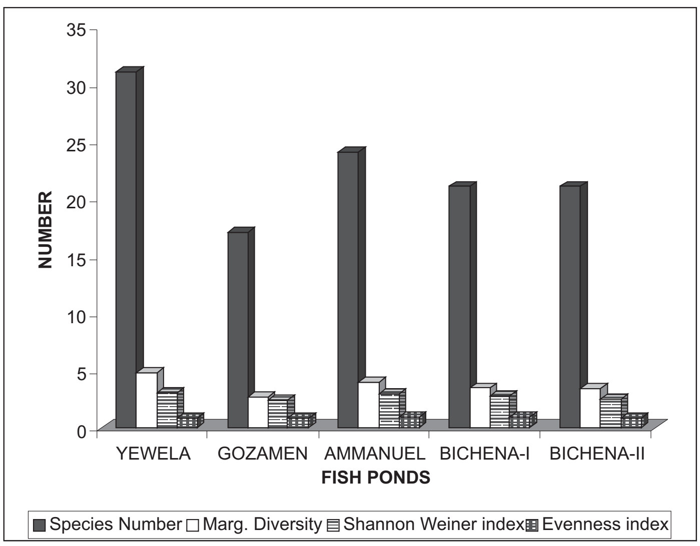

Figure 1: Species Richness and Diversity of Zooplankton in the Study Area.

Zooplankton Abundance

The average zooplankton density was 2510 individuals/l consisting of 49% Copepoda, 41 % Rotifera and 10% Cladocera. There was no significant difference (P>0.05) in the density of total zooplankton in the two categories of ponds, even though the ponds replenished with water from the surface waterbodies generally recorded higher population and diversity. In the ponds containing water sourced from surface water bodies lowest abundance of zooplankton was 475 individuals/l in Gozamen pond and maximum 589 individuals/l in Yewela pond, whereas in the pond containing water sourced from sub surface water bodies the lowest abundance of zooplankton recorded was 476 units/l in Bichena-I and maximum recorded was 500 units/l in Bichena-II.

Copepods were the dominant group in both ponds and constituted an average of 257 individuals/l with a range of 165–315 individuals/l in ponds containing water sourced from surface water bodies and an average of 238 individuals/l with a range of 235–240 individuals/l in pond containing water sourced from sub-surface water bodies respectively (Fig 2). The naupliar stages of copepods contributed significantly to the high number. All the species were recorded in ponds containing water sourced from surface water bodies, while only seven of the species were found in ponds containing water sourced from sub surface water bodies.

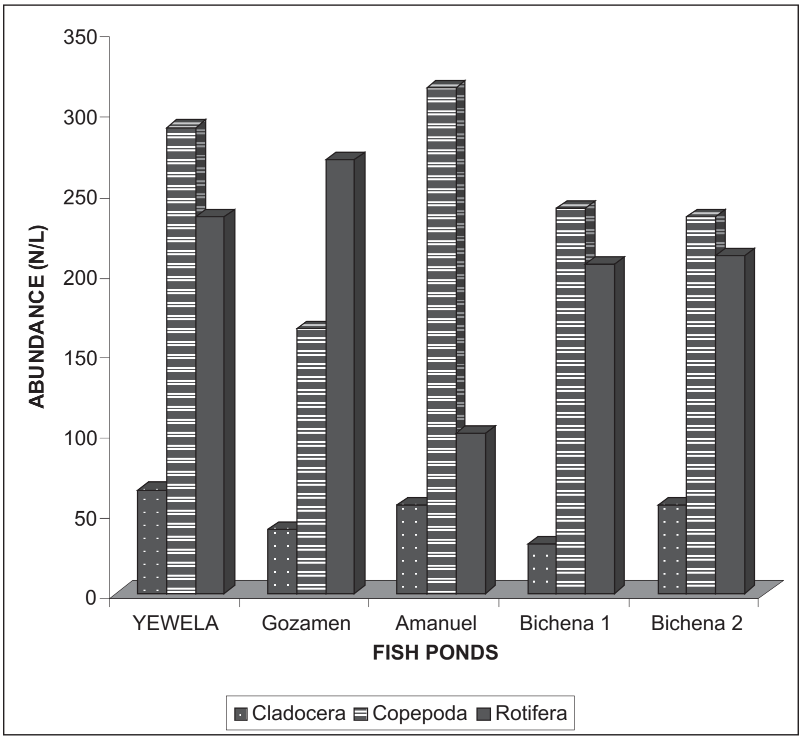

Figure 2: The Abundance of the Major Zooplankton Groups in Each of the Five Research Fish Ponds.

Rotifers were next to copepods in abundance; they contributed an average of 202 individuals/l with a range of 100–270 individuals/l in ponds containing water sourced from surface water bodies and an average of 208 individuals/l with a range of 205–210 individuals/l in ponds containing water sourced from sub surface water bodies respectively (Fig. 2). *Fifteen out of the nineteen rotifer species were recorded in* ponds containing water sourced from surface water bodies *while* ponds containing water sourced from sub surface water bodies had fourteen species recorded (Table 3).

The Cladocera was the least diverse of the three major groups with an average of 53 individuals/l and 43 individuals/l in ponds containing water sourced from surface water bodies and pond containing water sourced from sub surface water bodies respectively. Cladoceran number fluctuated between 40 and 64 individuals/l in ponds containing water sourced from surface water bodies. In ponds containing water sourced from sub-surface water bodies, highest value (55 individuals/l) was observed in Bichena-II and lowest value (31 individuals/l) in Bichena-I (Figure 2). Ten out of the fifteen Cladocera species were recorded in each of these two ponds.

The correlation co-efficient between the density of zooplankton and physicochemical parameters was calculated and given in Table-4. Zooplankton population density, did not show significant correlation ($P \leq 0.05$) with any of the environmental factors except Chloride (r= 0.687).

Table 4: Pearson Correlation Half Matrix Between Environmental Parameters and Zooplankton Densities of the Five Research Fish Ponds

	zooplankton (ind./L)	Tur. (NTU)	NO_3 (mg/l)	TH (mg/l CaCO3)	NH_3 (mg/l)	NO_2 (mg/l)	Cl. (mg/l)	DO (mg/l)	DO (%)	Tem. (^OC)	P^H	Cond. (µs/cm)
Tur.(NTU)	-0.218											
NO_3(mg/l)	-0.057	-0.233										
TH(mg/l $CaCO_3$)	0.168	-0.268	0.314									
NH_3 (mg/l)	-0.167	0.335	0.133	-0.102								
NO_2(mg/l)	0.041	0.127	-0.124	0.02	-0.139							
Cl.(mg/l)	.687(**)	0.066	-0.243	-0.224	-0.022	0.19						
DO(mg/l)	-0.13	-0.376	0.256	-0.336	-0.365	-0.121	-0.258					
DO (%)	-0.172	0.03	-0.172	-0.351	-0.16	.472(*)	-0.201	0.318				
Tem.(^OC)	-0.263	0.353	-.560(*)	-0.098	0.014	0.394	-0.032	-0.31	.604(**)			
P^H	0.002	-0.372	0.157	-0.161	0.193	0.28	-0.101	0.411	0.313	-0.046		
Cond.(µs/cm)	0.186	-0.319	0.272	.932(**)	-0.028	-0.191	-0.224	-0.33	-.461(*)	-0.181	-0.206	
TDS(mg/l)	-0.151	-0.305	-0.049	-0.34	-0.354	-0.148	0.077	0.04	0.177	-0.135	-0.346	-0.305

** Correlation is significant at $P \leq 0.01$ level

* Correlation is significant at $P \leq 0.05$ level

DISCUSSION

The zooplankton species recorded in this study are those commonly reported in the region (Brunelli and Cannicci, 1940; Wudneh, 1998; Dejen *et al.*, 2004; Imoobe and Akoma, 2008), and the composition in the five fish ponds irrespective of the source of water was characteristic of waterbodies with planktivorous fishes (Burgis *et al.*, 1973; Fernando, 1980; Zaret, 1980; Arcifa, 1984) as mainly small-bodied nauplii stages, small rotifers and cladocerans dominated the samples. The zooplankton analysis however, indicated that zooplankton abundance and diversity were slightly higher ($P>0.05$) on the average in ponds replenished with water from surface water bodies than in ponds receiving subsurface water. This slight variation may be due to either the conditions of the physico-chemical parameters, the availability of nutrients in the ponds or biological factors.

Factors such as light, temperature and nutrients usually play an important role in phytoplankton productivity (Hutchinson, 1967; Wetzel, 1983) and hence zooplankton productivity in aquatic ecosystems. Conductivity and TH were the only parameters with significantly lower values in ponds replenished with water from surface water bodies, the relatively higher values of water temperature, dissolved Oxygen and turbidity possibly as a result of high population of phytoplankton could have accounted for the slight higher zooplankton population and diversity as compared to ponds that received subsurface water.

Zooplankton abundance in tropical fish ponds have been reported in warmer waters (Sharma and Pant, 1984; Kiran *et al.,* 2007; Ikpi *et al.,* 2013), though a number of studies have also shown that zooplankton peaked in cold winter months (Bhuiyan and Nessa 1998a and b; Islam *et al.,* 2000) most probably due to the favourable conditions of the physico-chemical parameters and the availability of nutrients in the ponds during the period. Turbidity of water mostly results from suspended organic particles and the abundance of phytoplankton (Boyd, 1984); the high concentration of dissolved oxygen and oxygen supersaturation could be due to increased photosynthetic activity leading to oxygen production as a result of the high occurrence of phytoplankton and hence turbidity (Talling, 1986; Abdel-Tawwab *et al.*, 2005).

The observed lower population and diversity of zooplankton in Gozamen pond which even though is a surface water sourced pond like Amanuel and Yewela fish ponds could be attributed to the negative effect of sediment re-suspension. Gozamen pond was the only fish pond additionally stocked with *C. carpio,* which because of the feeding ecology as a fish that disturbs the bottom sediment (Dejen *et al.*, 2004), increased the turbidity of the water thereby negatively affecting the zooplankton abundance. The numerical variation in the zooplankton of the two groups of fish ponds might also be due to different biological parameters, including the fact that surface waters unlike subsurface waters are more likely to harbour resident plankton that would eventually flourish. The absence of clear interrelationships between the zooplankton population and the environmental conditions possibly indicates that the factors controlling the population may be biological such as trophic status of the ponds and selective herbivory. Further study, however, is needed for a sustainable pond fishery in these water bodies.

CONCLUSION

Water management in fishponds is an important factor that contributes to the success of fish culture, reducing the occurrence of fish disease and enhancing fish growth and survival. In this study, ponds replenished with water from surface water bodies except Gozamen fish pond with higher turbidity as a result of sediment re-suspension have shown better prospect in increased population and diversity of zooplankton that constitute important food item for young fish than ponds that received subsurface water.

ACKNOWLEDGEMENT

We are grateful to Dr. Koos Vijiberg for his initial criticism of the manuscript during its preparation.

REFERENCES

Abdel-Tawwab, M., Abdel-Hamid, M., Eid, Ali, E., Abdelghany, H. and El-Marakby. I. 2005. The Assessment of Water Quality and Primary Productivity in Earthen Fishponds Stocked with Stripped Mullet (Mugil cephalus) and Subjected to Different Feeding Regimes. *Turkish Journal of Fisheries and Aquatic Sciences* 5: 1-10.

Arcifa, M. S. 1984. Zooplankton composition of ten reservoirs in southern Brazil. *Hydrobiologia* 113: 137-145.

Bhatnagar, A. and Devi, P. 2013. Water quality guidelines for the management of pond fish culture. *International Journal of Environmental Sciences*, 3(6): 1980 -1997.

Bhuiyan, A. S. and Nessa, Q. 1998a. Seasonal variation in the occurrence of some zooplankton in a fish pond. *Bangladesh J.Fish. Res.* 2(2): 201-203.

Bhuiyan, A.S. and Nessa, Q. 1998b. A quantitative study of zooplankton in relation to the physico-chemical conditions of a freshwater fish pond of Rajshahi. *University J. Zool. Rajshahi Univ.* 17: 29-37.

Boyd, C. E. 1982. *Water quality Management of Pond Fish Culture*. Elsvier Sci. Pub. Co. Amsterdam- Oxford, New York.318pp.

Boyd, C. E. 1984. *Water Quality in Warmwater Fishponds*. Auburn University, Agricultural Experimental Station, Auburn, Alabama, USA.

Bronmark, C. and Hansson, L. A. 2005. *The Biology of Lakes and Ponds*. Oxford University Press, Oxford, pp 285.

Brunelli, G. and Cannicci. E. G. 1940. Le Caratteristiche Biologiche del Lag Tana. Missione di Studio al Lago Tana richerge limnologiche. *Boll. Chem. Biol R.Acc. Ita.* 3: 71–114.

Burgis, M. J., Darlington, J. P. E. C., Dunn, I. G., Ganf, G.C., Gwahaba, J. J. and McGowen, L. M. 1973. The biomass and distribution of organisms in Lake George, Uganda.

Proceedings. of the Royal. Society of London 184: 271-298.

Defaye, D. 1988. Contribution a la connaissance des Crustaces Copepodes d'Ethiopie. *Hydrobiologia*, 164: 103–147.

Dejen, E., Vijverberg, J., Nagelkerke, L. A. J. and Sibbing, F. A. 2004. Temporal and spatial distribution of microcrustacean zooplankton in relation to turbidity and other environmental factors in a large tropical lake L.Tana, Ethiopia. *Hydrobiologia* 513: 39–49

Dewan, S., Ali, M. and Islam, M. A. 1977. Study on the size and pattern of feeding of fries and fingerlings of three major carps, eg. *Labeo rohita* (Ham), *Catla catla* and *Cirrhina mrigala*. *Bangladesh J. Agri.* 2(2): 223-228.

Fernando, C.H. 1980. The freshwater zooplankton of Sri Lanka, with a discussion on tropical freshwater zooplankton composition. *Internationale Revue der gesamten Hydrobiologie*, 65: 85-125.

Hutchinson, G. E. 1967. *A Treatise on Limnology. Vol. II. Introduction to Lake Biology and the Limnoplankton*. John Wiley and Sons, Inc., New York, USA, 660 pp.

Ikpi, G.U., Offem, B.O. and Irom, B. O. 2013. Plankton Distribution and Diversity in Tropical Earthen Fish Ponds. *Environment and Natural Resources Research,* 3(3): 45 – 51.

Imoobe, T. O. T. and Akoma, O. C. 2009. Spatial variations in the composition and abundance of zooplankton in the Bahir Dar Gulf of Lake Tana, Ethiopia. *African Journal of Ecology* 48: 72 – 77.

Islam, M. N., Khan, T. A. and A. S. Bhuiyan. 2000. Ecology and seasonal abundance of some zooplankton of a pond in Rajshahi. *Univ. J. Zool.Rajshahi Univ.* 19: 25-32.

Islam, S. N. 2007. Physico-chemical Condition and Occurrence of Some Zooplankton in a Pond of Rajshahi University. *Research Journal of Fisheries and Hydrobiology* 2(2):21-25,

Ismail, M., H. Rahman, S. Ali, and K. H. Ahmed. 1984. Studies on limnology and some aspects of biology of *Oreochromis nilotica* (L.) in a pond Jurain,Dhaka. *Proc. 4th Nat. Zool. Conf. Bangladesh*, 97-105.

Jhingran, V. G. 1985. *Fish and Fisheries of India*. Hindustan Publishing Corporation, Delhi, India.

Kiran B. R., E. T. Puttaiah, and Kamath, D. 2007. Diversity and seasonal fluctuation of zooplankton in fish pond of Bhadra fish farm, Karnataka. *Zoos' Print Journal* 22 (12): 2935 – 2936.

Korinek, V. 1999. *A guide to limnetic species of Cladocera of African inland waters (Crustacea, Branchiopoda). Occasional Publication No. 1*. Geneva: The International Association of Theoretical and Applied Liminology, BTL.

Ludwig, J. A., and Reynolds, J. F. 1988. *Statistical Ecology. A Primer on Methods and Computing*. Wiley-Interscience, New York.

Nikolosky, G. V. 1963. *The Ecology of Fishes*. Academic Press. London, UK.

Prasad, B. B., and R. B. Singh. 2003. Composition, abundance and distribution of phytoplankton and zoobenthos in a tropical water body. *Nat. Envin. Pollut. Technol.* 2: 255-258.

Rahman, S. and Hassain, M.A. 2008. A study on the abundance of zooplankton of a culture and a non-culture pond of the Rajshahi University campus. *Univ. J. Zool. Rajshahi Univ.* 27: 35-41

Sharma, P. C., and M. C. Pant. 1984. Abundance and community structure of limnectic zooplankton in kumayun lake, India. *Hydrobiology* 69: 91-110.

Smirnov, N. N. 1996. Cladocera: the Chydorinae and Sayciinae (Chydoridae) of the world. In: *Guides to the Identification of the Micro Invertebrates of Continental Waters of the World* (Ed. H. Dumont). SPB Academic Publishing, Amsterdam.

Talling, J. F. 1986. The seasonality of phytoplankton in African lakes. In: M. Munawar and J.F. Talling (Eds.) *Seasonality of Freshwater Phytoplankton: A Global Perspective*. Junk Publ., Boston, USA, p139- 160.

Van de Velde, I. 1984. Revision of the African species of the genus *Mesocyclops Sars*, 1914 (Copepoda; Cyclopidae). *Hydrobiologia*, 109: 3–66.

Wetzel, R. G. 1983. *Limnology*. Second Edition. Saunders College Publishing, Philadelphia. 860pp.

Wudneh, T. 1998. *Biology and Management of Fish*

Stocks in Bahir Dar Gulf, Lake Tana, Ethiopia. Ph.D. thesis, Wageningen Agricultural University.

Zafar, A. R. 1964. On the ecology of algae in certain fish ponds of Hydrabad, India.I. Physicochemical complexes. *Hydrobiol.* 23: 179-195.

Zaret, T. M. 1980. *Predation and Freshwater Communities* New Haven & London, Yale University Press. pp 1-187.