

**LIMNOLOGY OF LENTIC ECOSYSTEMS OF BHUTAN
WITH EMPHASIS ON BIODIVERSITY OF ZOOPLANKTON**

By
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Submitted in fulfilment of the Degree of
Doctor of Philosophy in Zoology
of

**NORTH-EASTERN HILL UNIVERSITY
SHILLONG – 793 022**

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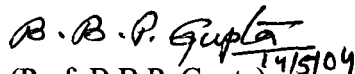
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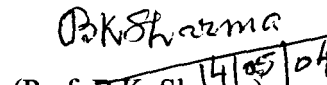
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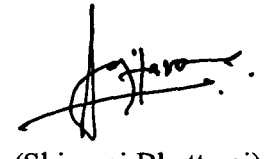
Declaration

I, Shivaraj Bhattarai, hereby declare that the subject of this thesis is the record of original work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else and that the thesis has not been submitted by me for any research degree in any other University/Institute.

This is being submitted to the North-Eastern Hill University for the degree of Doctor of Philosophy in Zoology.


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*This imperative piece of work of my life is dedicated to
my respected parents, Sri Chida Nanda Bhattarai and
Smt. Laxmi Devi; my better half Talsa and our
budding boys Arun and Suraj*

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(Shivaraj Bhattarai)

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INTRODUCTION

Water is a valuable natural resource and the basis of existence of all life forms in our biosphere. Besides, the watershed areas of large rivers were the birthplace of ancient human civilizations in the world. Water covers about seven tenths of the earth's surface of which only 2.53% is the freshwater (Anon, 2003). However, merely 0.5% of world's freshwater resources are accessible for human use as two-third is locked away in the glaciers and the continental ice while the remainder exists as soil moisture. The scarcity of accessible freshwater is of interest as well as concern since water is an indispensable liquid required for several purposes including drinking, sanitation, irrigation, navigation, and recreation as well as it is a valuable source of organic productivity.

The water bodies are intimately related to human life and his livelihood. These are intensively utilized for various purposes and are, hence, increasingly subjected to environmental stress. Demand upon freshwater resources has rapidly escalated due to radical increase in world population, industrialization, urbanisation and expansion of the agriculture and popularisation of a lifestyle that uses massive quantities of water. In the near future, there is concern that freshwater resources will deteriorate both in quality and quantity in many areas of the world. Global environmental problems such as global warming, acid rains and contamination with toxic chemicals are increasingly affecting the water ecosystems (Hanazato, 1999). Besides freshwater augmentation, wastewater and storm water, eutrophication of lakes and reservoirs, sewage and public health are another set of problems that threaten the existence of freshwaters. Therefore, inadequate protection of the quality and supply of freshwater can set important limits to sustainable development, health and sanitation, poverty eradication and biodiversity conservation. If the present situation is allowed to continue, a severe water stress is feared to occur by 2025 with greater impact on the developing countries (Anon, 2002). In recognition of the central importance of water resources to the planet's future, the year 2003 was proclaimed as the International Year of Freshwater by the General Assembly of the United Nations with the main objective of raising awareness of the importance of protecting and managing freshwater in a sustainable way. The significance of harvesting, conservation and management of freshwater resources is still being rated as highest priority for global attention and action.

Freshwater bodies vary from streams and rivulets to mighty rivers, huge lakes to reservoirs and recreational pools, bogs to swamps and marshes and man made ponds to paddy fields. Of these, lentic ecosystems such as lakes, reservoirs, ponds, paddy-fields, wetlands, bogs, ditches, drains, tree-holes, roadside puddles etc. form component of varied aquatic environs of the biosphere. They deserve special mention for supporting diverse array of aquatic and semi-aquatic communities besides being integral part of the landscape on the earth. In addition, these ecosystems are characterized by complex interactions between abiotic components of water and inhabitant living communities. Hence, investigations on physico-chemical and biotic attributes of different water bodies is essential to understand their structure and dynamics, assessment of biological productivity and formulation of strategies for their scientific management for various purposes.

The Kingdom of Bhutan, located on the southern slopes of the eastern Himalayas (Latitude: 26° 40'-28° 20' N; Longitude: 88° 45'-92° 25' E; area: 40,076 sq km) is characterized by rugged mountains and an intricate network of deep valleys, ravines, watercourses, drainage basins and moraines. Diverse geophysical features, climatic heterogeneity as well as its unique location at the juncture of the Palaearctic realm of temperate the Eurasian and the Indo-Malayan realms of the Indian subcontinent result in great diversity of ecosystems and, hence, impart this country the status of 'global hotspot' (Anon, 1998) for conservation of biological diversity. The country's great range in altitude and topography produces wide variations in climatic conditions. Dominant factor influencing the climate is the monsoon air-stream that blows north from Bay of Bengal bringing in heavy rainfall to the foothills and to exposed slopes and valleys further north, especially from June to September. The country is divided into three major geographical and climatic zones viz. the warm sub-Himalayan foothills, the cool sub-tropical to temperate inner Himalayas or mid-montane zone and temperate to alpine greater Himalayas.

Freshwater ecosystems of Bhutan cover only about 0.05% of the total land area while nearly 5.06% of land is under wetland cultivation (Anon, 1992). Further, aquatic habitats are scattered throughout the country in various ecological zones and these range from perennial rivers to seasonal rivulets, high altitude lakes and springs to lowland lakes, swamps, river floodplains and man-made reservoirs to village ponds and paddy fields. *Among these lentic habitats, small and big wetlands in the form of swamps and bogs*

comprise an integral part of rural landscape even though many such habitats had been turned into paddy-fields in the past. Besides providing aesthetic and wildlife values, these water bodies represent interesting ecotones that support wider diversity of aquatic communities but remain practically unexploited for harnessing their biogenic production potentials.

Limnology, the scientific study of all aspects of inland waters refers to a term that was first coined by Forel (1901) who, in turn, derived it from the Greek word “limnos” which literally meant the study of lakes. The subject came of age when the three-volume monograph, mainly the outcome of his research done on Lac Lemman (Lake Geneva), was published by Forel (1901). Further, prominent earlier scientific developments in this field included the study on distribution and ecology of crustacean zooplankton in Danish lakes by Müller (1867), recognition of lakes as functioning units or “microcosms” by Forbes (1887) and development of the widely used Winkler technique for dissolved oxygen determination by Winkler (1888). This was followed by first taxonomic work by Lauterborn (1893) on the rotifers in the Rhine river and the development of the Ekman dredge for quantitative sampling of lake sediments and their fauna by Ekman (1911), which was later modified to its present form by E.A. Birge. The establishment of the international Association for Theoretical and Applied Limnology (SIL) with the instrumental initiative of A. Thienemann and C.L. Naumann with 401 founding members from nearly all continents in 1922 was yet another important milestone in the history of Limnology. Besides, the development of the first mathematical model to predict water quality by Streeter and Phelps (1925) and the use of dissolved oxygen measurements for planktonic primary production and respiration rates in lakes by Vinberg (1934) and the same developed independently by Curtis (1935) were important developments in the limnological methods. Among other experimental works, the development of radioactive techniques to study phosphorous cycling in lakes by Hutchinson and Bowen (1947-1950) and the same technique to measure photosynthesis of phytoplankton by Nielsen (1952) and food consumption by zooplankton by Rodina and Troshin (1954) were important discoveries. The decade of 1960-1970 was mainly characterised by rapid development of electronic and analytical equipments and major shift in scientific emphasis from collection of observational data to experimental research. The period between 1970-2000, on the other hand, saw a rapid development in several dimensions of limnology mainly characterised by

significant progress in quantifying links between community structure and functioning and the role of fish therein, greater integration of fish ecology in limnology and growing interest in wetlands as systems (Kalff, 2002).

However, there are only limited limnological reports from the Himalayan and far eastern Himalayan regions. The studies in the region are almost entirely from India along with few reports from Nepal. A review of notable works from this region is by Hutchinson (1937, 1957b, 1967) which are the outcome of the Yale North India expedition during which some limnological and hydro-biological data of several aquatic ecosystems were collected including Dal lake, Manasbal, Wular and some ponds in Kashmir valley. Some mention of zooplankton taxa from this region is found in the works of Bond (1934), Edmondson and Hutchinson (1934) and Brehm (1936). Ecological problems of Kashmir lakes by Kaul and Zutshi (1971) and reviews on lake studies by Kaul (1977), Kaul and Handoo (1987) and Vass (1980) are some other recent works. Further, some other related works in the field of limnology and aquatic biology are that of Das (1974, 1976, 1978a), Das and Akhtar (1970, 1971), Zutshi and Vass (1970), Das and Pande (1978b), Quadri and Yousuf (1978, 1988), Sharma *et al.* (1979), Das and Upadhyaya (1979), Kaul (1982), Singh *et al.* (1982), Yousuf and Quadri (1985), Pandit (1999) and Sarwar (1999) from Kashmir and other western Himalayan region.

The study in the central Himalayan region, mostly from Nepal, was initiated by Ueno (1966), who for the first time, described five cladocerans and a copepod, *Arctodiaptomus nepalensis*, followed by a pioneering work of Löffler (1969) on the *High altitude lakes in Mt. Everest region*, which included studies on 24 lakes at an altitude ranging between 4500 to 5600 m on the south-west of Mt Everest. The later includes, besides the morphometry of the lakes, temperature profiles, study of few other abiotic parameters and inconclusive mention of some zooplankton community. Hickel (1973a and 1973b) enlisted four species of Cladocera and few phytoplankton in her limnological investigation of lakes in Pokhara valley, in western Nepal and in two ponds in Kathmandu valley respectively. Total of 22 species of cladocera and 14 species of copepods were reported from some parts in that country by Dumont and de Velde (1977). However, a total of 39 species of Cladocera are recorded from Nepal so far by Swar and Fernando (1979). Similarly, the only known work on the rotifers from Nepal is by Daems and Dumont (1974) where a total of 53 species are described. In the further east Sikkim, studies in this field are

still preliminary and reports on zooplankton diversity from this unique geographical location is not available yet. However, some works in aquatic ecology from this state include that of Jain *et al.* (1999, 2000) and Maharana *et al.* (2000), both reporting on nutrient dynamics, eco-tourism prospects and hydro-ecological studies respectively.

In the far eastern Himalayas, reports representing water quality of the sub-tropical environs are mostly from Meghalaya and these include works by Alfred and Thapa (1995), Sharma (1995,1999), Sharma and Lyngdoh (1999), Sharma and Wanswett (1999) and Sharma and Lyngskor (2003). A comparative account of temporal variations in physico-chemical parameters of fourteen lentic ecosystems of Meghalaya (Sharma, 2001) including diverse ecosystems such as reservoirs, ponds, impoundments, peat bog and rice field with comments on salient features and ecological relationships between the factors depicted typical sub-tropical characters, low electrolyte, soft nature of water and low chloride, sulphate, phosphate and nitrate concentrations. Similarly, major contributions to the zooplankton diversity in Meghalaya are by Sharma and Sharma, (1987, 1990, 1997, 1999). A total of 111 species (124 taxa) of freshwater rotifers belonging to 30 genera and 17 euratotarian families are included in the State Fauna Series 4: fauna of Meghalaya by Sharma and Sharma (1999a). Similarly, in the same document 41 species of Cladocera belonging to 29 genera and six families are reported (Sharma and Sharma, 1999b) belonging to the state of Meghalaya.

A recent report on aquatic ecosystem diversity of Bhutan (Anon, 1998) highlights lack of knowledge about their characteristic ecological features except for preliminary observations on water quality by Arora (1990) and Dhendup and Boyd (1994). In more recent times government's efforts are on to manage the watersheds in some parts of Bhutan. Noteworthy initiative in this direction is the launching of Bhutan Water Partnership, an inter-ministerial organization, to conserve the catchments and sustain the perennial river discharge (Gyeltshen, 2001). Lately, United Nations Environment Program (UNEP), along with remote-sensing experts from the International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu, Nepal, have conducted three years of research to assess the conditions of glaciers and glacial lakes in Bhutan and Nepal some of which have shown catastrophic outbursts in the past. Further it is reported that in the next half a decade or so, the Himalayas could experience many glacial lakes outburst floods (Bagla, 2002)

risking severely the lives and property of tens of thousands of people who live high in the mountains and in the downstream.

A review of related limnological literature indicates complete lack of any investigation dealing with micro-faunal diversity of water bodies or temporal variations in abiotic attributes in any particular aquatic biotope of Bhutan. An evaluation of the status of aquatic biological diversity (Anon, 1998) in freshwater biotopes of this country also exhibits complete lack of information about composition of planktonic communities, their synecology and production in general and zooplankton diversity in particular. The present pioneering study, therefore, assumes special significance in view of the mentioned lacunae and deals with water quality parameters of diverse aquatic environs of Bhutan and detailed limnological investigations in three selected water bodies of contrasting ecological attributes located in eastern part of the country. The observations are made on species composition, richness, succession, abundance, diversity, dominance, evenness, and ecology of plankton. In addition, the study deals with biodiversity of zooplankton communities in three aquatic biotopes and in depth analysis of Rotifera diversity in aquatic ecosystems of the kingdom in general and eastern Bhutan in particular.

MATERIALS AND METHODS

Study sites

Three different ecosystems of eastern Bhutan were selected for the detailed limnological studies on temporal variations of water quality and qualitative as well as quantitative composition of net plankton, zooplankton and phytoplankton. These water bodies were selected for their contrasting ecological attributes viz. Site 1 is a pond, Site 2, a peat bog and Site 3, a paddy-field. In addition, twenty-one other sites, mainly located in eastern Bhutan (Table: 1) were sampled for the purpose of studying the biodiversity of rotifers along with their basic water quality.

Site 1 (Pond): It is a small sub-tropical pond (Fig. 2a) with an area of about 1.0 ha and is located in a valley within Bumdeling Wildlife Sanctuary in Trashiyangtse district of East Bhutan (Fig. 1A) at an altitude of 1930 m ASL (Longitude: 91° 27' 23" E; Latitude: 27° 39' 53" N). The pond is surrounded by paddy-field and has a thick growth of *Acorus calamus* and *Scirpus mucronatus* around its fringes. Among other macrophytes, *Nitella* sp. is found abundantly in the water. Besides, plant species including *Fallopia convolvulus*, *Lindernia* sp., *Pogostemon linearis* and *Polygonum* sp. are found as semi-aquatic macrophytes growing in and around the pond. The water is generally clean except during few monsoon months when there is influx of muddy rainwater from the surrounding area.

Site 2 (Peat Bog): It is a small lowland water body consisting mainly of mat of moss (*Sphagnum* sp.) among the floating shrubs and trees growing on the *Sphagnum* mat. This peat bog (area: 1.25 ha) is located at 1930 m ASL very close to study Site 1. Besides having large quantity of decomposing moss in the pond water, there is luxuriant growth of filamentous algae, thereby, imparting dark colour to the water. Floating mat of sphagnum and other associated plants support number of trees including *Rhododendron* sp. *Quercus* sp. and *Pinus* sp., which grow rather poorly. However there is luxuriant growth of herbs such as *Acorus calamus*, *Fallopia convolvulus*, *Gultheria* sp., *Lindernia* sp., *Loyania ovalifolia*, *Lycopodium* sp., *Pogostemon linearis*, *Polygonum* sp. and *Scirpus mucronatus* on the sphagnum as well as around the boundaries of the bog.

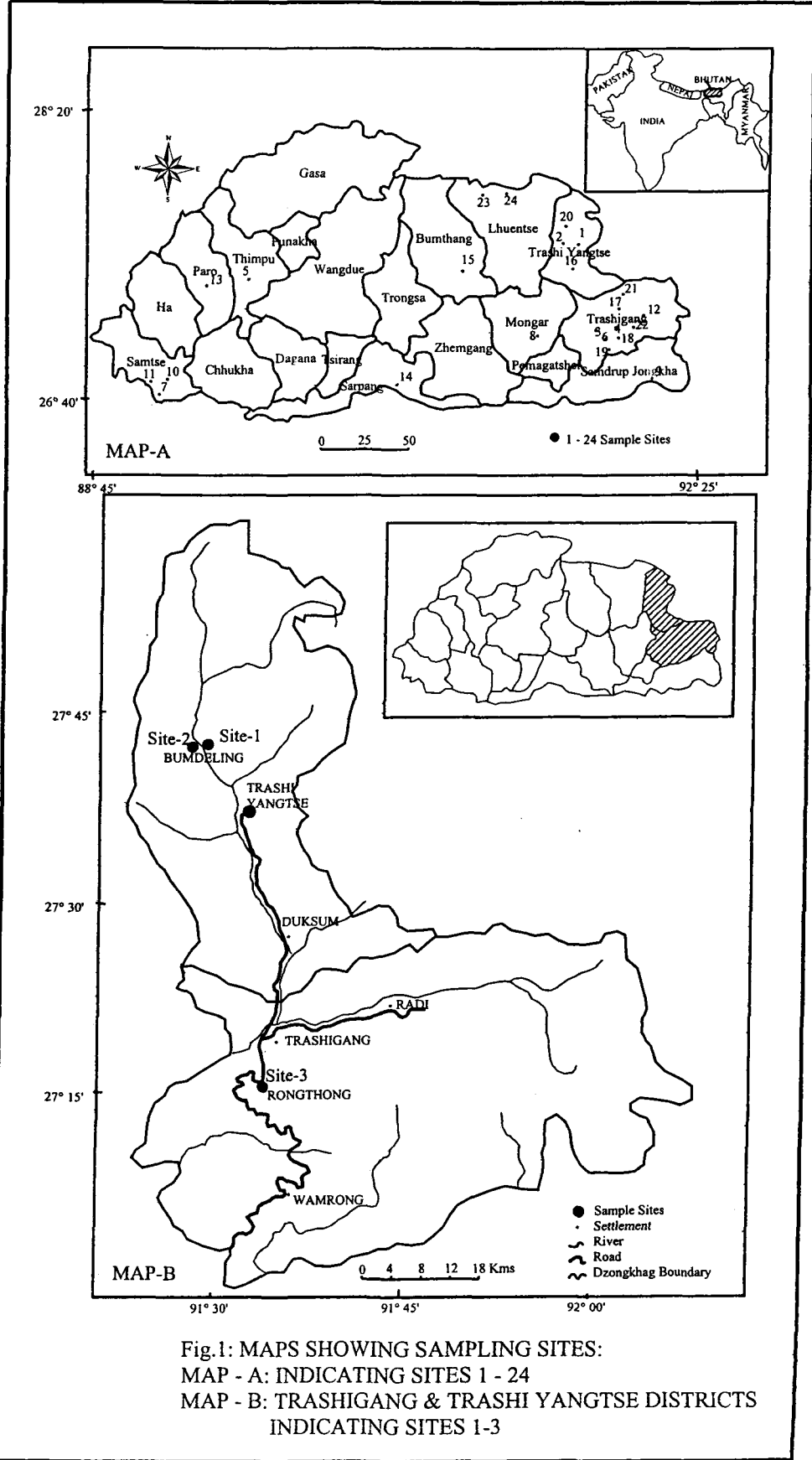


Fig.1: MAPS SHOWING SAMPLING SITES:
MAP - A: INDICATING SITES 1 - 24
MAP - B: TRASHIGANG & TRASHI YANGTSE DISTRICTS
INDICATING SITES 1-3

TABLE 1: SALIENT FEATURES OF STUDY SITES 1-24

Site No.	Location/name	Altitude (m)	Latitude (N)	Longitude (E)	Remarks
1	Nyagamtsho, Bumdeling	1930	27°39'53"	91°27' 23"	In Bumdeling Wildlife Sanctuary (sampled monthly for two years)
2	Dungtsho, Bumdeling	1930	27°39'53"	91°27'23"	Peat bog (sampled monthly for two years)
3	Rongthong paddy-field	1640	91° 31' 8"	27° 15' 48"	Water-logged throughout year (sampled monthly for two years)
4	Yonphula pond	3000	27°15' 48"	91°31' 8"	An ephemeral pond in east Bhutan
5	Thimphu sewage ponds	2500	89°40'	27°30'	Highly eutrophic ponds
6	College Pond (Kanglung)	1820	91°32'	27°30'	Small man made pond
7	Mechetar paddy-field (Samtse)	250	89° 04'	26°55'	At foothills in Samtse, south-west Bhutan
8	Ngatshang pond (Mongar)	1600	91°20'	27°20'	An ephemeral pond, on the way to Monger, East Bhutan
9	Fish ponds, S/Jongkhar	300	91°42'	26°52'	At Bhangtar in foothills of south-east Bhutan
10	Sibichang, Dorokha	1150	89°10'	26°58'	A small perennial pond on way to Dorokha, south-west Bhutan
11	Aalay (Mechetar), Samtse	300	89° 04'	26°55'	An ephemeral lake at foothills, Samtse
12	Danglingtsho Lake (Khaling)	3460	91°47'	27°12'	An alpine lake in East Bhutan
13	Kichu resort ponds (Paro)	2550	89°20'	27°30'	Recreational ponds in Paro, western Bhutan
14	Gelephug fishery ponds	250	90°30'	26°53'	Series of fish breeding pools in southern Bhutan
15	Bunthang- ponds	2600	90°45'	27°35'	Water loggings during rainy season near the town in central Bhutan
16	Bumdeling paddy-field	1920	27°39' 53"	91°27'23"	Paddy-field within Bumdeling Wildlife Sanctuary
17	Chephu (Radi, Trashigang)	2740	91°45'	27°20'	A shallow pond within an oak forest on the way to Merak from Radhi in east Bhutan
18	Kanglung paddy field	1830	91°32'	27°18'	A low temperate paddy-field in east Bhutan
19	Pangthang pond (Kanglung)	1850	91°32'	27°18'	A small pond with thick growth of <i>Acorus calamus</i>
20	Yorbingsho (Bumdeling)	2570	91°25'	27°42'	A shallow pond within Rhododendron and oak mix forest in Bumdeling Wildlife Sanctuary
21	Pond X (near Chephu), Radi	2740	91°45'	27°20'	A shallow pond within an oak forest on the way to Merak from Radhi in east Bhutan
22	Taktakpa (pond)	3150	91°32'	27°15'	A shallow pond within <i>Rhododendron</i> and oak mix forest (an hour walk above Yonphula air-strip)
23	Tshona (Singye Dzong)	4175	91°18'	28°00'	A glacial lake, located near Bhutan-China border, found partially melted in mid-May, about 1.25 km ² area
24	Terdalatsho (Singye Dzong)	4250	91°18'	28°00'	A glacial lake, found partially melted in mid-May, located near Bhutan-China about 1.5 km ² area

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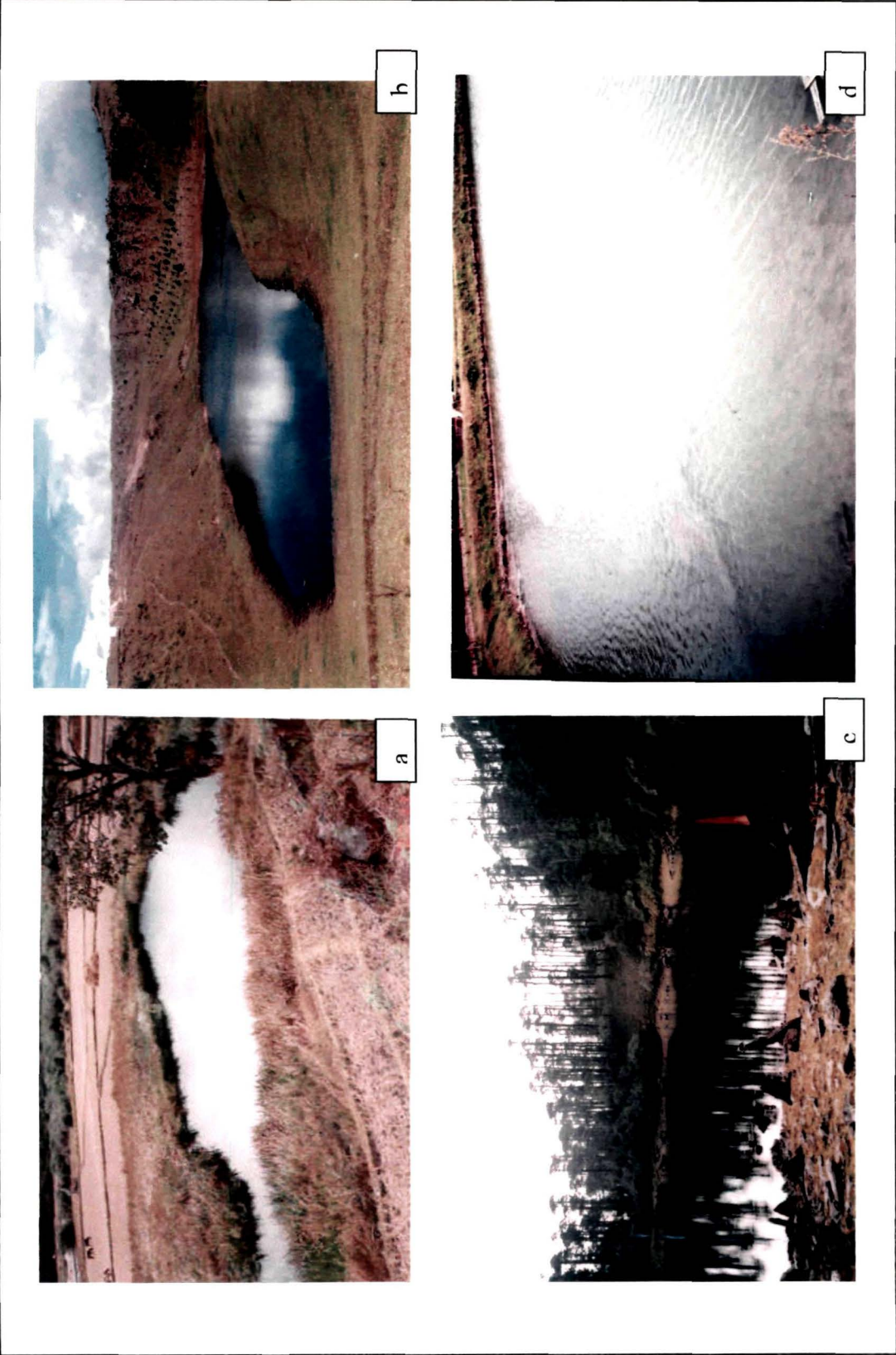


FIG. 2: VIEWS OF SOME SAMPLED WATERBODIES

Site 3 (Paddy-field): It is a small sub-tropical paddy field (area: 2 ha) located at a height of 1640 m ASL (Longitude: 91° 31' 8" E; Latitude: 27° 15' 48" N) in Trashigang district in eastern Bhutan. It was a wetland recently terraced and turned into paddy field and remains wet and swampy throughout the year. It is under cultivation only once in a year between June to October and remains fallow for the remaining months. The paddy field reportedly is not subjected to chemical fertilizers or to any pesticides. Organic manures such as cow dung or compost is applied sparingly prior to paddy plantations in the month of May. Several macrophytes that are commonly found in this paddy field include *Acmella spilanthus*, *Drymaria cordata*, *Fallopia convolvulus*, *Lindernia* sp., *Monocharia vaginalis*, *Nausturtium officinalis*, *Polygonum* sp. and *Scirpus mucronatus*.

To denote the periods before, during and after paddy cultivation, the terms pre-paddy season, paddy season and post-paddy season respectively are used in the text.

Sites 4-24: To study biodiversity of Rotifera as well as to obtain information on basic water quality parameters, water samples were collected from aquatic environs located in different parts of the country (Fig. 1A). However, due to paucity of standing water bodies in the country and owing to accessibility and logistic feasibility, most of the samplings were carried out in eastern Bhutan. These study sites comprised of diverse aquatic ecosystems such as high altitude lakes, sub-tropical ponds, ephemeral lakes and ponds, wetlands, paddy-fields, sewage stabilization pond and fishponds located at various altitudes and climatic regimes (Table: 1).

Methods of Study: For the limnology of three selected lentic ecosystems (Sites 1-3) mentioned above, water samples as well as qualitative and quantitative plankton samples were collected for two annual cycles at monthly intervals from February 2000-January 2002. Different abiotic parameters namely water temperature, transparency, pH, specific conductivity, dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, calcium, magnesium, chloride, sodium, potassium, sulphate, phosphate, nitrate, silicate, dissolved organic matter and total dissolved solids were studied to ascertain temporal variations in three selected ecosystems in east Bhutan. To ascertain the water quality of other diverse aquatic bodies, basic abiotic parameters namely temperature, pH, dissolved

oxygen, free carbon dioxide, specific conductivity, total alkalinity, total hardness, calcium, magnesium and chloride were recorded.

Air and water temperatures were recorded using a centigrade thermometer. pH and specific conductivity were measured with pH and conductivity meter respectively. Dissolved Oxygen was estimated by modified Winkler's method and other mentioned chemical parameters were analyzed by following A.P.H.A. (1992). The rainfall data was obtained from Trashiyangtse and Kanglung meteorological stations. While only qualitative plankton samples were collected and analyzed for rotifer communities to enumerate rotifer diversity at Sites 4-24, both qualitative and quantitative samples were collected for the limnological investigations in three selected lentic ecosystems and analysed for phytoplankton as well as zooplankton communities. All the plankton samples were collected using nylobolt plankton net (No.#25) and preserved in 5 % formalin in the field. Qualitative samples were obtained by towing the plankton net in different water bodies and quantitative samples were collected from sampling stations by filtering 25 litres of water. Various planktonic taxa were identified following important works of Edmondson (1959), Kutikova (1970), Smirnov (1971, 1976), Koste (1978), Michael and Sharma (1988), Battish (1992), Segers (1995), Sharma and Sharma (1999) and other relevant literatures. Quantitative enumeration of planktonic communities was done using the Sedgwick-Rafter counting cell.

Percentage similarities between various planktonic communities were calculated vide

Sorenson's index (Sorenson, 1948):

$$C_s = \frac{2C}{a+b} \times 100$$

whereas, C = species common in two samples
 a = number of species of one collection
 b = number of species of next collection.

Species diversity was determined as follows:

(i) Shannon's Index:

$$H' = -\sum p_i \ln p_i, \text{ (Ludwig \& Reynolds, 1988)}$$

whereas, $p_i = n/N$

n = density of individual species;

$N = \text{Total density}$

(ii) Menhinick's Index:

$$D_{mn} = S/\sqrt{N} \text{ (Menhinick, 1964)}$$

whereas, $S = \text{Total number of species};$

$N = \text{Total density.}$

Species dominance was calculated using

(i) Berger-Parker's Index:

$$d = N_{\max} / N \text{ (Berger and Parker, 1970)}$$

whereas, $N_{\max} = \text{density of most abundant species};$

$N = \text{Total density}$

(ii) Simpson's index (Ludwig and Reynolds, 1988)

$$\lambda = \sum \frac{n_1(n_1 - 1)}{N(N - 1)}$$

whereas, $n_1 = \text{density of individual species};$

$N = \text{Total density.}$

Evenness was calculated as,

$$E_1 = H' / \ln S \text{ (Pielou, 1975)}$$

whereas, $H' = \text{species diversity}$

$S = \text{species richness.}$

ANOVA was applied to ascertain significance of variations of the recorded abiotic and biotic parameters during the studied period, between three selected sampling sites as well as in individual ecosystems.

Ecological relationships were computed among abiotic and biotic factors and between abiotic and biotic factors in individual ecosystems by simple correlation coefficients (r) and indicated as r_1 , r_2 and r_3 for Site 1 (pond), Site 2 (peat bog) and Site 3 (paddy-field), respectively. Statistical significance of the stated correlations was ascertained by application of student's 't-test'. In addition, multiple step-wise regressions were established between plankton abundance and abiotic parameters.

OBSERVATIONS

I. ABIOTIC FACTORS (TEMPORAL CHANGES) IN SELECTED ECOSYSTEMS

The monthly variations of different abiotic factors at Site 1 (Pond), Site 2 (Peat bog) and Site 3 (Paddy-field) were studied and the results are represented in Figs. 3-22. In addition, annual ranges and mean values (\pm SD) for two years are presented in Tables: 2-4. The salient features of the recorded parameters are described below:

Temperature: Air temperature recorded at Sites 1, 2 and 3 ranged between 13.1-28.9° C ($18.4 \pm 4.3^\circ$ C), 10.5-28.8° C ($18.2 \pm 5.0^\circ$ C) and 9.4-28.3° C ($21.2 \pm 5.68^\circ$ C) respectively. Maximum air temperature was noted during July 2001 at all the study sites.

Water temperature ranged between 10.5–24.9° C ($17.2 \pm 4.0^\circ$ C), 9.1–26.0° C ($16.4 \pm 4.8^\circ$ C) and 9.0-25.6° C ($19.7 \pm 4.9^\circ$ C) at three study sites respectively (Table: 2-4). Water temperature broadly followed identical trends at all the sites and registered unimodal annual patterns of monthly fluctuations. In the pond, water temperature gradually increased between February-June (11.8-21° C) during first year and February-July (12.1-24.9° C) during the second year of study. Its peak value was observed in the month of July in second year with mean temperature remaining identical during both the years in this water body. In the peat bog, maxima was recorded in September in the first year and peak coincided with that of pond during July in the second year.

In the paddy-field, water temperature fluctuated more distinctly with a sharp increase from February-May (13.8-25° C) followed by a constant high temperature during the next three months. After a slight decline in August, temperature increased marginally during another three months followed by a sharp decline in November during the first year of the study. In the second year, water temperature gradually increased during pre-monsoon period till the peak was attained in June 2001. There was a marginal decline in mid-monsoon (July-August) and minor fluctuations were seen till October. Temperature dropped sharply from October onwards and minima was registered during December. Therefore, at all three sites, water temperature reached peak during the second year of study and the paddy-field recorded marginally higher mean temperature than the other two sampled water bodies.

TABLE 2: TEMPORAL VARIATIONS OF PHYSICO-CHEMICAL PARAMETERS AT SITE 1 (POND)

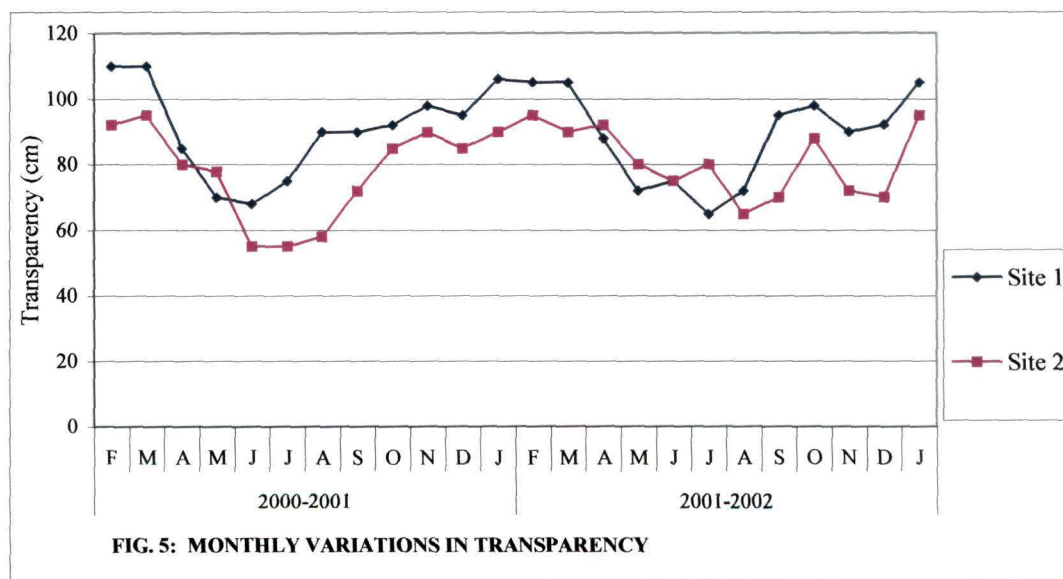
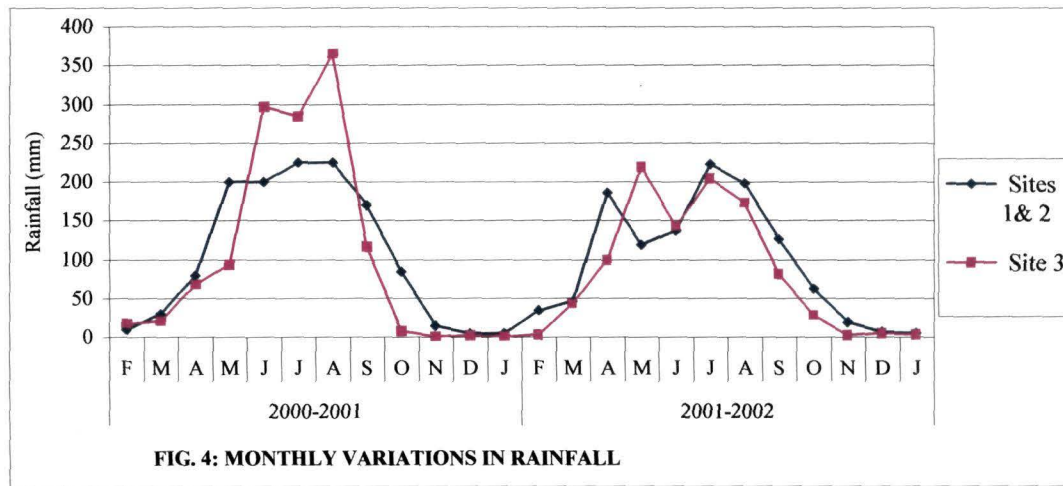
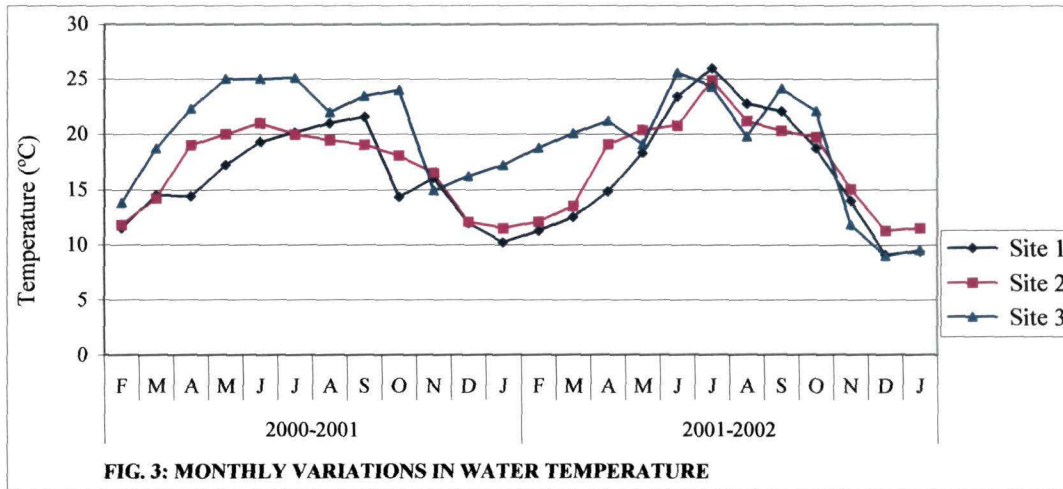
Parameters	First year		Second year		Study period	
	Range	Mean \pm SD	Range	Mean \pm SD	Range	Mean \pm SD
Air Temperature ($^{\circ}$ C)	13.1-23.9	17.6 \pm 3.1	13.1-28.9	19.1 \pm 5.2	13.1 - 28.9	18.4 \pm 4.3
Water Temperature ($^{\circ}$ C)	11.5-21.0	16.9 \pm 3.5	11.3-24.9	17.5 \pm 4.5	10.5 - 24.9	17.2 \pm 4.0
Rainfall (mm)	5.0-225.0	104.2 \pm 92.8	5.0-222.4	96.7 \pm 78.1	5.0 - 225.0	100.4 \pm 84.0
Transparency (cm)	68.0-110.0	90.8 \pm 14.3	65.0-105.0	88.5 \pm 14.3	65.0 - 110.0	89.6 \pm 14.1
Specific Conductivity (μ S/cm)	23.0-62.0	33.3 \pm 12.6	22.0-45.0	33.5 \pm 8.5	22.0 - 62.0	33.4 \pm 10.5
pH	6.53-7.35	6.90 \pm 0.28	6.56-7.80	6.93 \pm 0.41	6.53 - 7.80	6.91 \pm 0.34
Dissolved Oxygen (mg/l)	2.4-10.4	6.1 \pm 2.7	2.8-9.2	5.5 \pm 2.1	2.4 - 10.8	5.4 \pm 2.3
Free Carbon dioxide (mg/l)	3.5-10.0	5.6 \pm 2.1	3.2-24.0	8.5 \pm 5.5	3.2 - 24.0	7.1 \pm 4.3
Total Alkalinity (mg/l)	20.0-30.0	23.8 \pm 3.3	17.0-30.0	25.8 \pm 3.7	17.0 - 30.0	24.8 \pm 3.6
Total Hardness (mg/l)	12.0-20.0	15.0 \pm 2.9	11.0-26.0	17.8 \pm 4.2	11.0-26.0	16.4 \pm 3.8
Calcium (mg/l)	2.9-8.4	4.9 \pm 1.8	2.9-7.4	4.8 \pm 1.3	2.9 - 8.4	4.9 \pm 1.5
Magnesium (mg/l)	0.8-3.5	2.2 \pm 1.0	1.9-4.5	3.0 \pm 0.9	0.9 - 4.5	2.6 \pm 1.0
Sodium (mg/l)	1.2-5.0	3.0 \pm 1.2	2.2-6.8	5.0 \pm 1.8	1.2 - 6.8	3.5 \pm 1.6
Potassium (mg/l)	3.1-6.2	4.7 \pm 1.3	3.5-9.3	6.1 \pm 1.9	2.5 - 9.3	5.4 \pm 1.7
Chloride (mg/l)	2.0-5.6	4.4 \pm 1.2	2.5-6.5	4.1 \pm 1.2	2.5 - 6.5	4.2 \pm 1.2
Sulphate (mg/l)	0.18-0.76	0.50 \pm 0.23	0.12-0.68	0.33 \pm 0.14	0.12 - 0.76	0.41 \pm 0.21
Phosphate (mg/l)	0.006-0.06	0.03 \pm 0.02	0.004-0.05	0.02 \pm 0.02	0.004 - 0.06	0.03 \pm 0.02
Nitrate (mg/l)	0.009-0.17	0.06 \pm 0.04	0.04-0.09	0.06 \pm 0.02	0.009 - 0.17	0.06 \pm 0.03
Silicate (mg/l)	2.5-62.5	16.8 \pm 17.8	6.5-18.9	10.5 \pm 5.9	2.5 - 62.5	13.7 \pm 13.4
Dissolved Organic Matter (mg/l)	0.3-4.5	2.24 \pm 1.45	0.75-2.42	1.65 \pm 0.99	0.3 - 4.5	1.95 \pm 1.25
Total Dissolved Solids (mg/l)	0.32-0.85	0.53 \pm 0.20	0.24-0.56	0.45 \pm 0.13	0.24 - 0.85	0.49 \pm 0.17

TABLE 3: TEMPORAL VARIATIONS OF PHYSICO-CHEMICAL PARAMETERS AT SITE 2 (PEAT BOG)

Parameters	First year		Second year		Study period	
	Range	Mean \pm SD	Range	Mean \pm SD	Range	Mean \pm SD
Air Temperature ($^{\circ}$ C)	12.8-23.2	17.5 \pm 3.0	10.5-28.8	18.7 \pm 6.5	10.5 - 28.8	18.2 \pm 5.0
Water Temperature ($^{\circ}$ C)	10.2-21.6	16.02 \pm 3.9	9.1-26.0	16.9 \pm 5.8	9.1 - 26.0	16.4 \pm 4.8
Rainfall (mm)	5.0-225.0	104.2 \pm 92.8	5.0-222.4	96.7 \pm 78.1	5.0 - 225.0	100.4 \pm 84.0
Transparency (cm)	55.0-95.0	77.9 \pm 14.7	65.0-95.0	81.0 \pm 10.7	55.0 - 95.0	79.5 \pm 12.7
Specific Conductivity (μ S/cm)	17.0-62.0	41.1 \pm 16.0	23.0-60.0	43.7 \pm 14.2	17.0 - 62.0	42.4 \pm 14.8
pH	5.74-6.51	6.19 \pm 0.28	5.69-6.58	6.14 \pm 0.3	5.69 - 6.58	6.17 \pm 0.27
Dissolved Oxygen (mg/l)	1.9-9.6	3.5 \pm 2.3	1.2-5.6	3.3 \pm 1.1	1.2 - 9.6	3.4 \pm 1.8
Free Carbon dioxide (mg/l)	12.0-65.0	20.3 \pm 14.2	11.2-36.0	18.7 \pm 7.4	11.2 - 65.0	19.5 \pm 11.1
Total Alkalinity (mg/l)	12.0-36.0	21.8 \pm 8.3	11.0-34.0	22.6 \pm 7.6	11.0-36.0	22.2 \pm 7.8
Total Hardness (mg/l)	10.0-25.0	16.3 \pm 4.8	14.0-34.0	20.3 \pm 6.0	10.0-34.0	18.3 \pm 5.7
Calcium (mg/l)	3.2-8.4	5.6 \pm 2.1	4.2-7.4	5.5 \pm 1.1	3.2 - 8.4	5.6 \pm 1.6
Magnesium (mg/l)	1.1-4.3	2.6 \pm 0.9	1.9-8.1	3.8 \pm 1.8	1.1 - 8.1	3.2 \pm 1.5
Sodium (mg/l)	2.0-6.2	3.4 \pm 1.3	2.0-6.8	4.6 \pm 1.5	2.0 - 6.8	4.0 \pm 1.5
Potassium (mg/l)	2.0-10.0	5.4 \pm 2.9	1.8-13.5	5.1 \pm 4.1	1.8 - 13.5	5.3 \pm 3.5
Chloride (mg/l)	2.8-5.6	4.5 \pm 1.0	3.8-6.2	5.0 \pm 0.8	2.8 - 6.2	4.7 \pm 0.9
Sulphate (mg/l)	0.88-2.99	1.81 \pm 0.79	0.85-2.32	1.37 \pm 0.52	0.85 - 2.99	1.59 \pm 0.69
Phosphate (mg/l)	0.01-0.17	0.06 \pm 0.06	0.006-0.066	0.03 \pm 0.03	0.006 - 0.17	0.05 \pm 0.05
Nitrate (mg/l)	0.075-0.15	0.11 \pm 0.03	0.003-0.18	0.09 \pm 0.05	0.003 - 0.18	0.1 \pm 0.04
Silicate (mg/l)	5.0-15.0	10.1 \pm 2.8	2.5-11.5	7.2 \pm 3.8	2.5 - 15.0	8.6 \pm 3.6
Dissolved Organic Matter (mg/l)	1.72-10.72	5.38 \pm 3.36	0.9-8.5	2.87 \pm 2.32	0.9 - 9.6	4.13 \pm 3.1
Total Dissolved Solids (mg/l)	0.22-0.84	0.52 \pm 0.18	0.36-0.85	0.55 \pm 0.16	0.22 - 0.85	0.54 \pm 0.17

TABLE 4: TEMPORAL VARIATIONS OF PHYSICO-CHEMICAL PARAMETERS AT SITE 3 (PADDY-FIELD)

Parameters	First year		Second year		Study period	
	Range	Mean \pm SD	Range	Mean \pm SD	Range	Mean \pm SD
Air Temperature ($^{\circ}$ C)	15.1-28.0	22.4 \pm 5.1	11.2-28.3	20.1 \pm 6.2	9.4 - 28.3	21.2 \pm 5.6
Water Temperature ($^{\circ}$ C)	13.8-25.1	20.6 \pm 4.2	9.0-25.6	18.8 \pm 5.9	9.0 - 25.6	19.7 \pm 4.9
Rainfall (mm)	0.7-297.2	106.3 \pm 132.8	3.1-203.8	83.5 \pm 82.4	0.7 - 364	94.9 \pm 108.7
Specific Conductivity (μ S/cm)	36.0-83.0	55.9 \pm 14.4	35.0-88.0	49.7 \pm 15.8	35.0 - 88.0	52.8 \pm 15.1
pH	6.53-7.41	6.9 \pm 0.28	6.21-6.94	6.6 \pm 0.2	6.21 - 7.41	6.75 \pm 0.2
Dissolved Oxygen (mg/l)	2.4-9.6	6.2 \pm 2.6	4.5-13.6	7.8 \pm 2.3	2.4 - 13.6	7.0 \pm 2.5
Free Carbon dioxide (mg/l)	0.0-11.6	4.7 \pm 3.0	2.5-20.0	6.1 \pm 4.7	0.0 - 20.0	5.4 \pm 4.0
Total Alkalinity (mg/l)	16.8-40.0	26.4 \pm 6.9	18.0-40.0	29.4 \pm 5.8	16.8 - 40.0	27.9 \pm 6.4
Total Hardness (mg/l)	14.0-38.0	20.5 \pm 7.0	15.0-40.0	23.6 \pm 7.9	14 - 40.0	22 \pm 7.5
Calcium (mg/l)	4.6-13.7	7.7 \pm 2.9	4.2-12.6	6.6 \pm 2.2	4.2 - 13.7	7.2 \pm 2.6
Magnesium (mg/l)	1.6-7.4	3.1 \pm 1.6	2.3-8.3	4.1 \pm 1.8	1.6 - 8.3	3.6 \pm 1.8
Sodium (mg/l)	1.7-6.8	4.4 \pm 1.7	1.0-8.4	4.6 \pm 2.1	1 - 8.4	4.5 \pm 1.9
Potassium (mg/l)	2.3-6.0	3.3 \pm 1.1	2.0-8.0	4.8 \pm 1.9	2.0 - 8.0	4.1 \pm 1.7
Chloride (mg/l)	2.0-5.5	4.2 \pm 1.0	2.5-7.0	5.1 \pm 1.3	2.0 - 7.0	4.6 \pm 1.2
Sulphate (mg/l)	0.92-2.92	1.7 \pm 0.61	1.19-3.06	1.8 \pm 0.7	0.92 - 3.06	1.77 \pm 0.65
Phosphate (mg/l)	0.01-0.06	0.02 \pm 0.01	0.006-0.078	0.02 \pm 0.02	0.006 - 0.078	0.02 \pm 0.02
Nitrate (mg/l)	0.02-0.22	0.1 \pm 0.07	0.01-0.506	0.1 \pm 0.14	0.01 - 0.506	0.1 \pm 0.11
Silicate (mg/l)	2.5-50.0	19.0 \pm 15.8	2.5-60.0	21.9 \pm 21.3	2.5 - 60.0	20.4 \pm 18.4
Dissolved Organic Matter (mg/l)	0.9-5.2	2.8 \pm 1.51	0.75-11.25	3.1 \pm 3.21	0.75 - 11.25	2.92 \pm 2.46
Total Dissolved Solids (mg/l)	0.24-0.58	0.4 \pm 0.1	0.24-0.6	0.4 \pm 0.11	0.24 - 0.6	0.4 \pm 0.11



Rainfall: Total rainfall at the first two sites (pond and peat bog) ranged between 5.0-225.0 mm (100.43 ± 84.0 mm) with the peak rainfall of 225.0 mm during the months of July and August 2000. At Site 3 (paddy-field), higher range between 0.7-364.0 mm (94.9 ± 108.75 mm) was observed with the peak rainfall of 364.1 mm during August 2000. Considerable quantity of rainfall was received between May-September with small showers throughout the year (Fig. 4) with an average annual rainfall of 1205 mm at Sites 1 and 2 and 1138 mm at Site 3. While at Sites 1 and 2, quantity of rainfall during the first year (1250 mm) and the second year (1160.4 mm) differed marginally, in the paddy-field total rainfall in first year was higher (1275 mm) compared to second year (1002.1 mm) of the study period. Further, at these sites, single maxima was observed during July and August in the first year (225 mm) depicting a unimodal pattern of monthly fluctuations of the rainfall. However, a bimodal pattern of monthly variations, with two maxima, was seen in the second year with primary maxima (222.4 mm) during July and secondary during April (186.3 mm) with relatively less showers in between. Similarly in the paddy-field, peak was registered in August during the first year and two maxima were observed during the second year with the primary maxima (203.8 mm) in July and secondary (219.1 mm) in May. Further the quantity of rain dropped sharply from August onwards at all sites during both the years with relatively dry winters (November-February).

Transparency: Sechhi disc transparency was recorded presently only in the pond and the peat bog and its monthly values fluctuated with a wider range in the pond between i.e., 65.0-110.0 cm (89.6 ± 14.7 cm), and it ranged between 55.0-95.0 cm (79.4 ± 12.6 cm) in the peat bog depicting unimodal pattern of variations at both sites during the study period (Fig. 5). Further, at both sites, transparency was generally low during the rainy season particularly between May-September and higher penetration of light was noticed during the dry months.

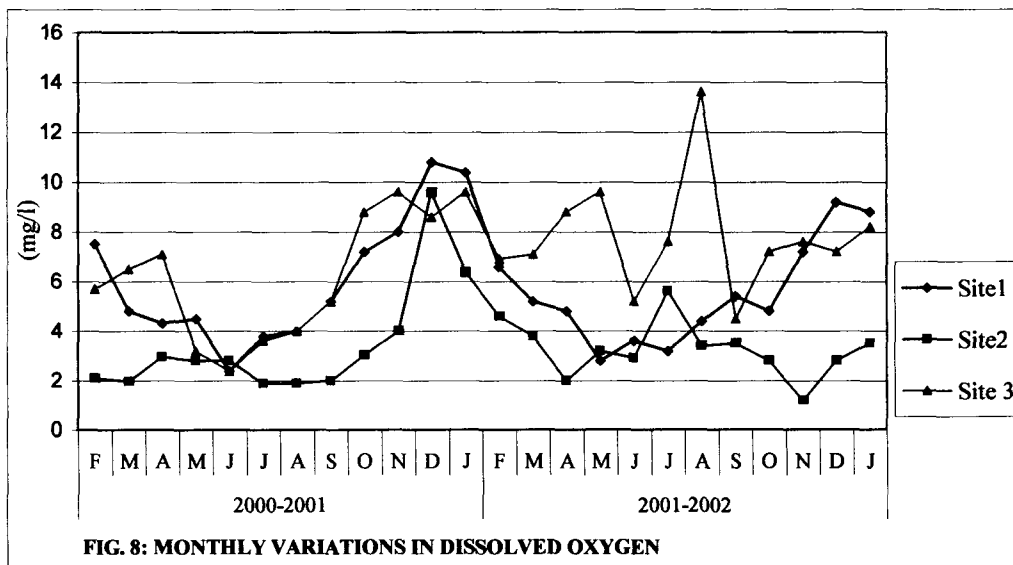
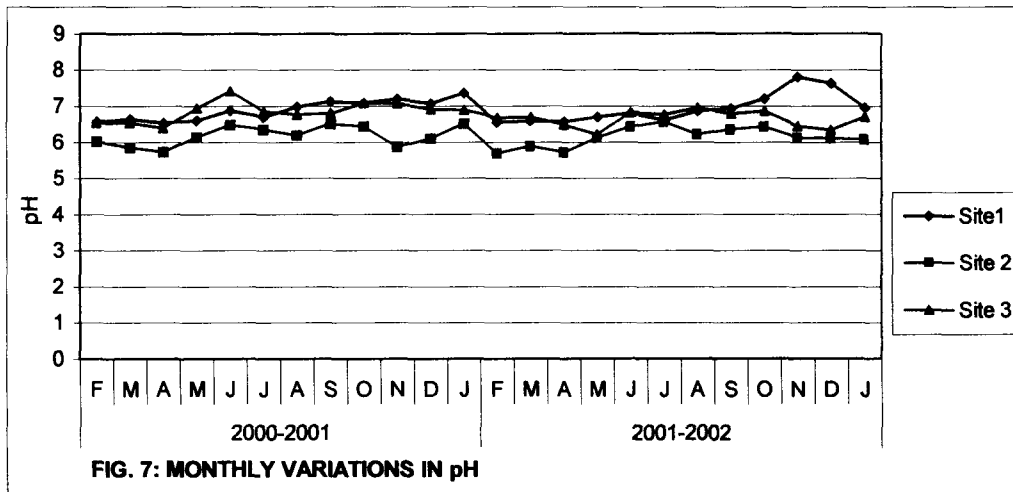
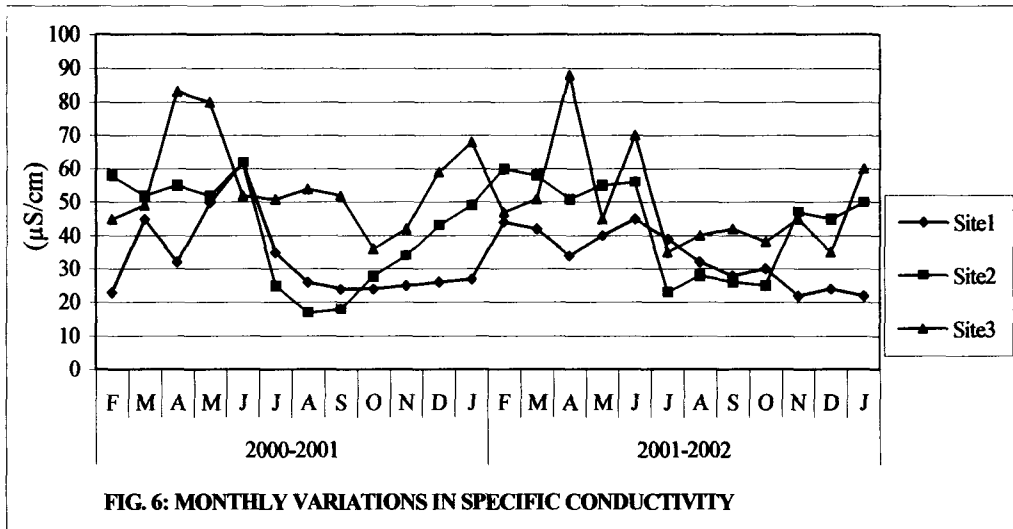
In the pond (Site 1), mean and ranges were identical during both the years and peak in transparency was recorded during February-March in the first year. Period between April-June depicted continuous decline and July-November a steady increase in penetration of light. After a marginal decrease in December the transparency in this water body increased again to attain maxima during January in the first year of study. A similar trend was observed in second year with minima registered in July. In the peat bog (Site 2),

transparency showed a wider range of fluctuations in the first year i.e., between 55.0-95.0 cm against a relatively narrow range of 65.0-95.0 cm during the second year and registered peak value (95.0 cm) during the months of March 2000, February 2001 and January 2002, while minima was registered during June and July 2000. In the first year of study period, transparency gradually dropped from March-July and was almost constant till the end of the year. In the second year, transparency was relatively high until July (75-95 cm) but it reduced sharply in August and kept fluctuating during the next five months with an overall increase till the end of the study period.

Specific Conductivity: The recorded conductivity values showed low ionic concentrations in general with relatively narrow ranges between 22-62 $\mu\text{S}/\text{cm}$ ($33.4 \pm 10.5 \mu\text{S}/\text{cm}$) in the pond (Site 1) and 17-62 $\mu\text{S}/\text{cm}$ ($42.38 \pm 14.8 \mu\text{S}/\text{cm}$) in the peat bog (Site 2) and with wider range and higher mean of 35-88 $\mu\text{S}/\text{cm}$ ($52.8 \pm 15.2 \mu\text{S}/\text{cm}$) in the paddy-field (Site 3) during the study period. Mean ionic concentration registered were in the order of Site 1 > Site 3 > Site 2. At all the sites, conductivity was lower during the rainy season and higher during the dry months (Fig 6).

In the pond (Site 1), specific conductivity exhibited marginal variations in annual ranges but showed identical mean values during the study period i.e., 23-62 $\mu\text{S}/\text{cm}$ ($33.3 \pm 12.6 \mu\text{S}/\text{cm}$) in the first year and 22-45 $\mu\text{S}/\text{cm}$ ($33.5 \pm 8.4 \mu\text{S}/\text{cm}$) in the two annual cycles respectively. Further, it depicted a bimodal pattern of monthly fluctuation during the first year with primary maxima in June and secondary during March (45 $\mu\text{S}/\text{cm}$). It was followed by a sharp decline and minima was attained in August. Specific conductivity remained fairly constant throughout winter till January in this ecosystem. However during the second year, secondary maxima was observed in February (44 $\mu\text{S}/\text{cm}$) followed by a marginal decline during next two months and a rise to primary maxima in June. It continued to drop gradually after this throughout the year with the two annual ranges and their mean values remaining identical.

In peat bog (Site 2), monthly variations in specific conductivity exhibited a wider range (17-62 $\mu\text{S}/\text{cm}$) but relatively a lower mean value ($41.9 \pm 16 \mu\text{S}/\text{cm}$) during the first year as against a narrow range and higher mean between 23-60 $\mu\text{S}/\text{cm}$ ($43.6 \pm 14.1 \mu\text{S}/\text{cm}$) during the second year. Peak and minima were observed in June and August respectively during the first annual cycle and depicted broadly a bimodal pattern of monthly fluctuation.



The secondary maxima ($58 \mu\text{S/cm}$) was recorded in February and remained generally high till June. This was followed by a sharp drop in the specific conductivity during July and thereafter it remained generally low throughout the monsoon while it recorded gradual rise again from September till the primary maxima of the second year in February. In the second year, conductivity showed slight fluctuations till June with an overall increase to give rise to secondary maxima ($56 \mu\text{S/cm}$) but dropped sharply in July and remained low till October. With a sharp increase, a tertiary maxima was observed in January ($50 \mu\text{S/cm}$), thereby depicting trimodal pattern of monthly fluctuations.

The specific conductivity in the paddy-field (Site 3) depicted a bimodal pattern in the first year and a trimodal in the second year with higher mean in pre- and post-paddy seasons. With the ranges remaining identical during the two years, higher mean of $55.9 \pm 14.4 \mu\text{S/cm}$ was seen during the first year and $49.7 \pm 15.8 \mu\text{S/cm}$ during the second year. After primary maxima during April in first year, there was gradual decline in specific conductivity up to July. It remained low and almost constant till September and further dropped to minima ($38 \mu\text{S/cm}$) in October. It was followed by a gradual increase till secondary maxima was attained in January. During the second year, peak conductivity was registered during April and the second maxima was noticed during June ($70 \mu\text{S/cm}$). After a sharp decrease in July (minima) it remained generally low till December but increased again marginally and depicted tertiary maxima ($60 \mu\text{S/cm}$) in January.

pH: Hydrogen ion concentration showed significant variations among the three study sites (Fig. 7) with wide ranges in the pond (Site 1) and the paddy-field (Site 3) between 6.53-7.8 (6.91 ± 0.34) and 6.21-7.41 (6.75 ± 0.27) respectively depicting generally slightly acidic to slightly alkaline nature of the water. While at Site 2 (peat bog), pH ranged between 5.69-6.58 (6.17 ± 0.27) and thereby affirmed an acidic character of the peat bog.

At Site 1, pH was relatively low during monsoons with no significant variations between the annual ranges and the mean values. It broadly depicted a unimodal pattern with the primary maxima in January during the first year and the peak in November during the second year of the study. Similarly, the minima was observed in May in first year with relatively low pH during the monsoon. The peat bog (Site 2) exhibited acidic pH throughout the study period with a narrow range of 5.74-6.51 (6.19 ± 0.28) in the first year and a somewhat wider range i.e., between 5.69-6.58 (6.14 ± 0.28) in the second year.

Generally, the water was relatively more acidic during the dry months and depicted a trimodal pattern during the first annual cycle and a broadly bimodal pattern of fluctuation during the second year. During the first year of study, pH decreased from February onwards till minima (pH 5.69) was noticed during April. This was followed by tertiary maxima (pH 6.49) during June, while there were regular fluctuations in the next three months and two maxima of equal magnitude (pH 6.51) were noticed during October and January of the first annual cycle. During the second year, pH registered slight decline initially that was followed by a gentle increase during the monsoon and peak was recorded during July. Subsequently, pH declined and increased marginally again and depicted secondary maxima (pH 6.42) in October while it gently decreased in the next month and remained constantly low till January.

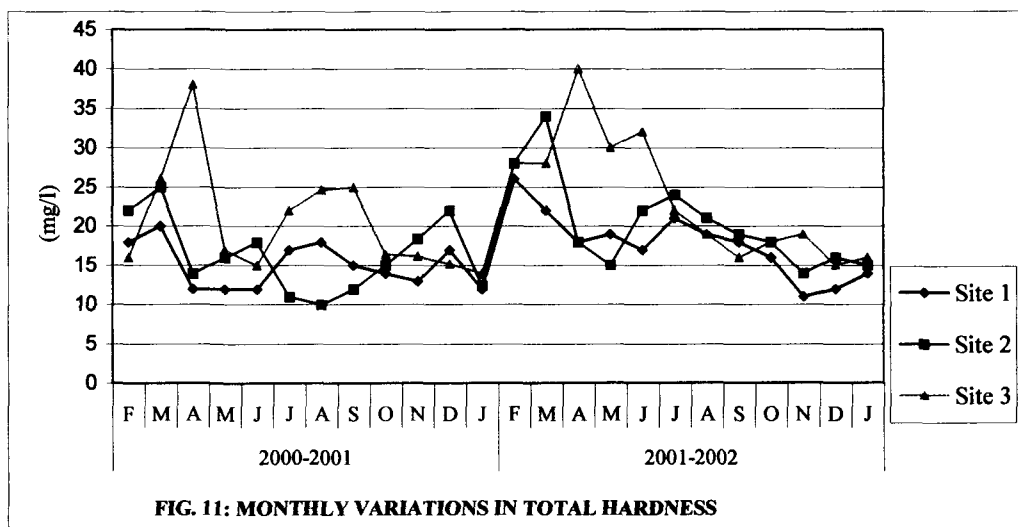
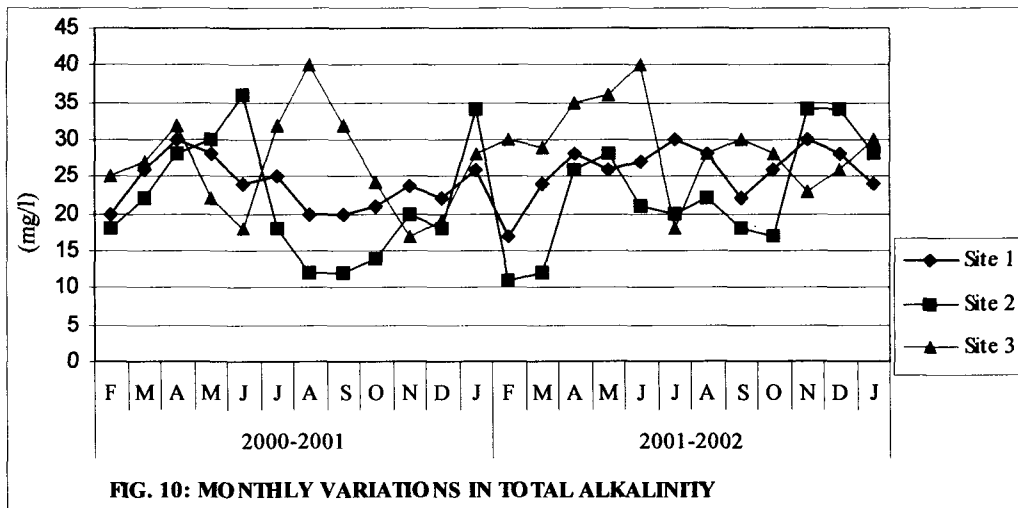
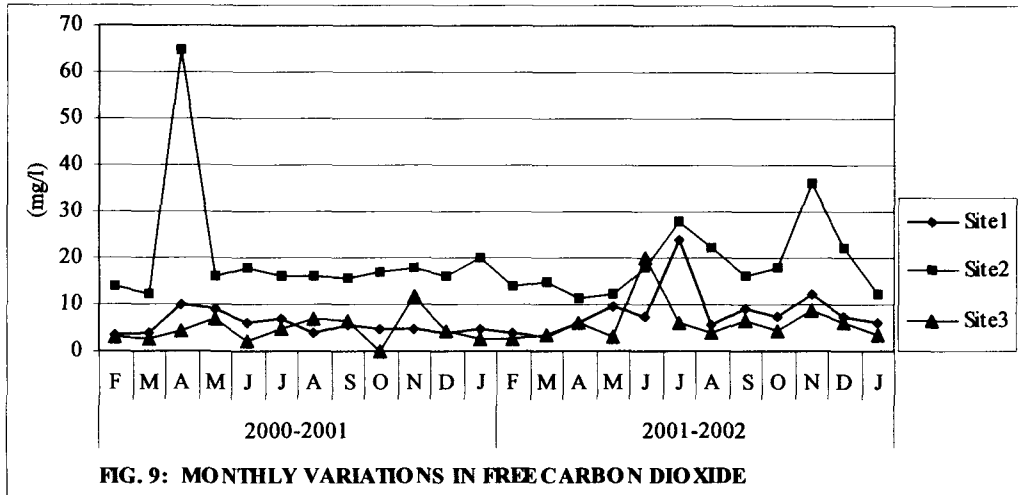
However at Site 3 (paddy-field), pH varied more distinctly during the two annual cycles of the study period i.e., between 6.53-7.41 (6.58 ± 0.28) and between 6.21-6.94 (6.64 ± 0.22), respectively. Further, pH was relatively more acidic during pre- and post-paddy seasons (winters) in this ecosystem. During June in the first year of study, water was mildly alkaline (pH 7.41) but pH decreased during September till the end of the year. During the second year there was a gradual decline in pH from February till a minima (pH 6.21) was attained in May while it increased during June and remained almost circum-neutral. On the other hand, during second annual cycle marginal decline in pH was noted during November-December.

Dissolved Oxygen: This dissolved gas depicted temporal variations ranging between 2.4-10.8 mg/l (5.4 ± 2.3 mg/l) in the pond, 1.2-9.6 mg/l (3.4 ± 1.8 mg/l) in the peat bog and 2.4-13.7 mg/l (7.0 ± 2.5 mg/l) in the paddy-field. At all the three sites, relatively lower oxygen was generally observed annually between June-July and particularly in the first year the minima were registered during June in the pond as well as in the paddy-field and during July in the peat bog (Fig. 8).

In the pond (Site 1), monthly fluctuations in dissolved oxygen content were more gradual and depicted bimodal pattern of fluctuation during the study period. A relatively wider range of 2.4-10.4 mg/l (6.08 ± 2.68 mg/l) was observed during the first year. After secondary maxima (7.5 mg/l) during February, a gradual decline in dissolved oxygen content was noticed from March-June till its minima was registered. It was, however,

followed by a gentle increase to primary maxima in December during the first year. Similar trend of temporal fluctuations was seen during second year of study with a relatively narrow range of 2.8-9.2 mg/l (5.5 ± 2.1 mg/l). In the peat bog (Site 2), dissolved oxygen ranged relatively more widely between 1.9-9.6 mg/l (3.5 ± 2.3 mg/l) during the annual cycle and recorded a relatively narrow range i.e., between 1.2-5.6 mg/l (3.28 ± 1.13 mg/l) during the second year. The percentage saturation of oxygen during the two annual cycle recorded mean values of 27.7 % and 26.3% respectively. Further, it clearly followed a unimodal pattern of monthly fluctuation in the first year with the peak during December, which, in turn, was followed by a steady decline in the beginning of the second year of study. However during the second year, even though a broadly unimodal pattern was noticed, maxima recorded during July was of lesser magnitude (5.6 mg/l). The minima was recorded during November, 2001 (1.2 mg/l) with percentage saturation of about 10%. In the paddy-field, narrow range of dissolved oxygen (2.4-9.6 mg/l) with lower mean (6.2 ± 1.57 mg/l) was seen during the first year while higher oxygenation was prevalent in this water body during succeeding annual cycles with a range of 4.5-13.6 mg/l (7.8 ± 2.3 mg/l). Broadly a trimodal pattern of monthly variations of dissolved oxygen concentration during the first year with two equal maxima in November and January and a secondary in April (7.1 mg/l) were recorded in this water body. However, a distinct bimodal pattern of monthly variations with primary maxima in August and secondary in May (9.6 mg/l) were recorded during the second year of study in this ecosystem.

Free Carbon dioxide: It fluctuated between 3.2-24.0 mg/l (7.1 ± 4.3 mg/l) in the pond (Site 1), recorded a wider range in the peat bog (Site 2) i.e., between 11.2-65.0 mg/l (19.5 ± 11.1 mg/l) and a relatively narrow range of 0.0-20.0 mg/l (5.4 ± 3.95 mg/l) was noticed in the paddy-field (Site 3). Further, the peat bog exhibited higher concentration of free CO₂ throughout the study period. This gas recorded considerable variations in range and mean between the first and the second year of the study period at Site 1. Whereas a narrow range of 3.5-10.0 mg/l with less annual fluctuations was recorded in the first year, it ranged more widely between 3.2- 24.0 mg/l (7.06 ± 4.27 mg/l) in the second year depicting a unimodal pattern of its monthly fluctuations (Fig. 9). Further, during the first year, its minima was recorded in February followed by a marginal increase subsequently, which, in turn, registered a maxima in April. While it remained generally low and constant during the



remaining part of the first year, the peak concentration was registered in July with generally low free CO₂ in pre- and post monsoon seasons in the second year of the study. At Site 2 (peat bog), monthly variations in free CO₂ content ranged more widely during the first year between 12.0-65.0 mg/l (20.3 ± 14.2 mg/l) and followed a unimodal pattern with a peak in April. This was followed by a steep decline up to around mean value till the following April when the minima was registered. In the second year a relatively narrow range of 11.2-36.0 mg/l (18.7 ± 7.4 mg/l) with a bimodal pattern of fluctuations was observed with the primary maxima in November and secondary in July (28.0 mg/l). At Site 3 (paddy-field), free CO₂ ranged narrowly between 0.0- 11.6 mg/l (4.65 ± 3.05 mg/l) in the first year and more widely in second year with a range between 2.5-20 mg/l (6.14 ± 4.7 mg/l). It broadly depicted a trimodal pattern of fluctuation in the first year with two maxima of equal magnitude (7.0 mg/l) in May and August and primary maxima in November. On the other hand, free CO₂ was not detected during October 2000 in this ecosystem. During the second year, a unimodal pattern was observed with peak in June (20.0 mg/l) and generally low content during the paddy and post paddy seasons except a marginal increase in November (8.5 mg/l).

Total Alkalinity: It was exclusively represented by methyl orange or bicarbonate alkalinity and was found to be generally low (< 40 mg/l) at all the sites. It fluctuated within narrow ranges in the pond and the peat bog i.e., between 17.0-30.0 mg/l (24.8 ± 3.6 mg/l) and 11.0-36.0 mg/l (22.2 ± 7.8 mg/l) respectively and between 16.8-40.0 mg/l (27.9 ± 6.4 mg/l) in the paddy-field.

In the pond, the ranges and mean values of total alkalinity were identical during two annual cycles and depicted broadly bimodal patterns of monthly fluctuations (Fig. 10). Total alkalinity sharply increased from February-April and attained primary maxima (30 mg/l) in the first year. It was followed by a gradual decline during the monsoon till September and increased till second maxima (26.0 mg/l) during January. However during the second year, its minima was recorded in February, which, in turn, was followed by an increase during the monsoon. The maxima of equal magnitude (30.0 mg/l) were registered during July and October during the second year of the study in this ecosystem.

In the peat bog, identical ranges and mean values were depicted annually with distinct bimodal patterns of monthly fluctuations. During the first year, a gradual increase

in total alkalinity from February-June culminated into a peak (36.0 mg/l) in June. This was followed by a sharp decrease during the monsoon with lowest alkalinity during August-September (12.0 mg/l). It gradually increased from October onwards and depicted secondary maxima (34.0 mg/l) during January. In the second year, as at Site 1, minima (11.0 mg/l) was observed during February, which was followed by a gradual increase till secondary maxima in May (28.0 mg/l). As in the first year, there was decrease in the total alkalinity with the onset of the monsoon till October. However, after a slight increase in its concentration, two secondary maxima of equal magnitude (34.0 mg/l) were observed during November and December. Broadly trimodal pattern of monthly variations of total alkalinity was recorded with similar ranges and mean values during the first and the second years of study in the paddy-field. The peak concentration of total alkalinity (40.0 mg/l) content was noticed during August 2000 and June 2001. During the first year there was a gradual increase from February-April forming secondary maxima (32.0 mg/l), which, in turn, was followed by a sharp decline during May-June. After an abrupt increase during July-August (peak) there was a sharp decline again during the subsequent months and minima was registered in November. Further, total alkalinity gradually increased during the next two months and tertiary maxima (28.0 mg/l) was registered in January. However during the second annual cycle, total alkalinity continued to increase during the pre-paddy season till the primary maxima was recorded in June (40.0 mg/l). There was steep decline in total alkalinity during July followed by an increase in September to attain secondary maxima (30.0 mg/l). After a gradual decline from October-November, it further increased and gave rise to tertiary maxima (30.0 mg/l) in December.

Total Hardness: At all the three sampled sites, total hardness was generally low; it ranged between 11.0-26.0 mg/l (16.4 ± 3.8 mg/l) in the pond and recorded relatively wider ranges i.e., between 10.0-34.0 mg/l (18.3 ± 5.7 mg/l) and 14.0-40.0 mg/l (22.0 ± 7.5 mg/l) in the peat bog and the paddy-field respectively. Further, generally lower hardness was recorded during the monsoon at all the sites.

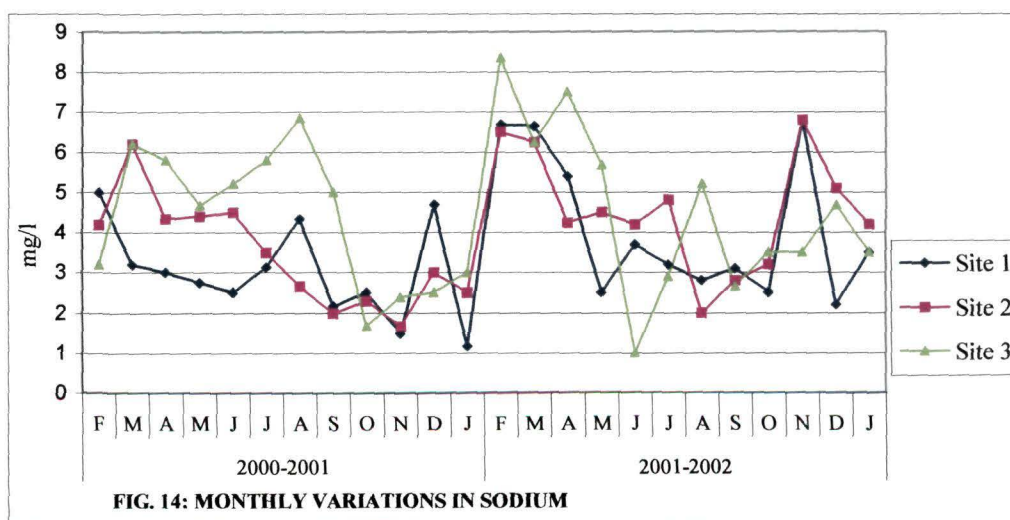
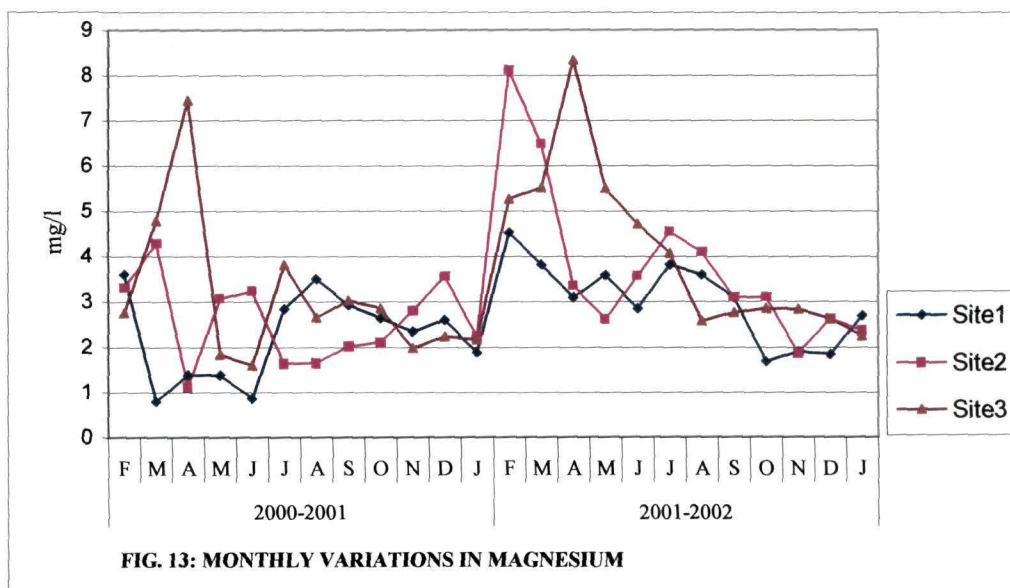
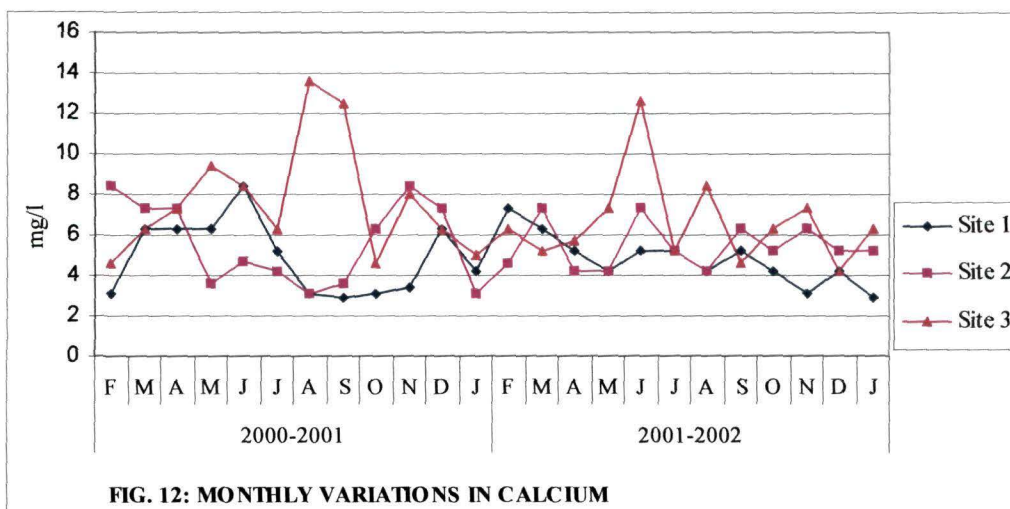
In the pond, hardness ranged between 12.0-20.0 mg/l (15.0 ± 2.9 mg/l) in the first year and between 11.0-26.0 mg/l (17.8 ± 2.2 mg/l) in the second year. Further, monthly variations of total hardness depicted roughly a trimodal pattern (Fig. 11) during the first annual cycle and a bimodal pattern in the succeeding year. Total hardness declined sharply

from April-June and thereafter marginally increased and attained secondary maxima in August during the first year (18.0 mg/l) as well as in second year (19 mg/l). However, in the first year, primary maxima was recorded during March and the tertiary maxima (17.0 mg/l) during December. There was then a steep rise in total hardness till peak was registered during February. During the second year, it continued to decline until November after which it increased during the last two months of the study.

Similarly, a narrow range of 10.0-25.0 mg/l (16.3 ± 4.8 mg/l) with a trimodal pattern of monthly variations of total hardness was seen in the peat bog during the first year. However, a relatively wider range of 14.0-34.0 mg/l (20.3 ± 6.0 mg/l) with a bimodal pattern of monthly variations was observed in the second year of the study period. During the first year, the primary maxima (25.0 mg/l) was observed in March, a tertiary maxima in the June (18.0 mg/l) and minima (10.0 mg/l) in August. Hardness increased gradually from August and depicted secondary maxima in December. This was followed by a sharp decline in January after which total hardness gradually increased to attain peak in March during the second annual cycle. However in the second year, total hardness in this water body declined during April-May and increased once again to attain secondary maxima (24.0 mg/l) during July. It was then followed by a gradual decrease from August till the end of the study period.

A bimodal pattern during the first year and a unimodal in the second year of study with identical ranges and the mean values of total hardness were registered in the paddy-field. During both the years, it increased from February onwards and depicted primary maxima (38.0 mg/l) in March during the first year and peak in April during the second year of the study. There was then a sharp decline in total hardness till June (15.0 mg/l) in the first year and up to September (16.0 mg/l) in the second year. However in the first year, the total hardness increased marginally and recorded secondary maxima (25.0 mg/l) in September and declined and registered minima (14.0 mg/l) during January. In the second year, lesser fluctuations of total hardness were registered after September with broadly constant values (15.0-19.0 mg/l).

Calcium: This study depicted low calcium content in general in all three ecosystems, which ranged between 2.9-8.4 mg/l (4.9 ± 1.5 mg/l) in pond, 3.2-8.4 mg/l (5.6 ± 1.6 mg/l)



in the peat bog and relatively higher mean and wider range of 4.2-13.7 mg/l (7.2 ± 2.6 mg/l) in the paddy-field.

With annual ranges and mean values remaining similar during both the years, calcium content in the pond (Site 1) as well as in the peat bog (Site 2) depicted bimodal patterns of monthly fluctuation in the first year and broadly multimodal trend in the succeeding year. In the pond (Site 1), calcium gradually increased from February-March and remained constant for the next two months followed by the peak (8.4 mg/l) in June. There was a sharp decline during monsoon till October followed by a rise to attain secondary maxima (6.3 mg/l) in December during the first year. In the second year, calcium content registered primary maxima in February (7.4 mg/l) following which there was gradual decline till April and regular fluctuations after May exhibiting generally low calcium content. The minima (2.9 mg/l) was registered in January during the second year in the pond. However in the peat bog, it ranged more widely between 3.2-8.4 mg/l during first year and between 4.2-7.4 mg/l during the second year. The peak was registered in February during the first annual cycle. Thereafter it declined and exhibited constant low value throughout monsoon till September. It, however, increased till secondary maxima (8.4 mg/l) in November, while then dropped again gradually to minima in January. During the second annual cycle, calcium content fluctuated constantly and remained generally lower than first year.

In the paddy-field (Site 3), a trimodal pattern of monthly fluctuations of calcium content was depicted during the study period with relatively wider range and higher mean between 4.6-13.7 mg/l (7.7 ± 2.9 mg/l) during the first year. The calcium content increased gradually from February till secondary maxima was attained during May (9.5 mg/l), which was followed by a decline during the next two months of the paddy season. However, it increased again and depicted the peak (13.7 mg/l) in August and this was followed by equally sharp decline in October (4.6 mg/l). It increased once again in November and registered tertiary maxima (8.0 mg/l). However in the second year, a relatively narrow range of 4.2-12.6 mg/l (6.6 ± 2.2 mg/l) was recorded. Calcium was consistently low till April but sharply increased during the next two months and attained primary maxima in June. With constant fluctuations, secondary maxima in August (8.4 mg/l), tertiary in November (7.4 mg/l) and minima (4.2 mg/l) of calcium concentration in December were recorded in the paddy-field.

Magnesium: Low magnesium concentration was recorded at all three sites with a relatively narrow range of 0.87-4.53 mg/l (2.64 ± 1.0 mg/l) in the pond, 1.13-8.11 mg/l (3.2 ± 1.54 mg/l) in the peat bog and 1.6-8.34 mg/l (3.6 ± 1.77 mg/l) in the paddy-field during the study period.

Magnesium ranged between 1.9-4.5 mg/l (3.3 ± 0.9 mg/l) in the pond during second year and recorded a relatively narrow range i.e., between 0.8-3.5 mg/l (2.2 ± 1.0 mg/l) during the preceding annual cycle. Further, it depicted a bimodal pattern of monthly fluctuations in the first year with the primary maxima in February followed by minima in March (Fig. 13). After remaining generally low till June, magnesium concentration increased gradually and exhibited second maxima (3.5 mg/l) in August. It further increased till the end of the year and culminated to a peak in February 2001. However in second year, July recorded second maxima (3.8 mg/l) while during the rest of the monsoon and post-monsoon period magnesium remained low in this ecosystem. In the peat bog (Site 2), annual ranges and mean values differed between two years. A narrow range of 1.1-4.3 mg/l (2.6 ± 0.9 mg/l) was noted in the first year and relatively wider range of 1.9-8.1 mg/l (3.8 ± 1.8 mg/l) in the second year and generally low magnesium content was recorded during the monsoon. Further, a trimodal pattern of fluctuation during the first year and a bimodal in the second year was depicted in this water body. Similarly, during the first year of study, primary maxima was recorded in March and minima in April (1.13 mg/l). It increased marginally and registered a tertiary maxima (3.23 mg/l) in June. This alkaline earth metal increased during post-monsoon period (November-December) and resulted in secondary maxima (3.6 mg/l). It increased sharply during winter season from December-February (peak) in the second year. However in second year, there was a sharp decline during March-May followed by an increase to secondary maxima (4.6 mg/l) in July. It then remained low during the rest of the study period till January. At Site 3 (paddy-field), magnesium content was significantly higher in pre-paddy season of the study period. Its mean concentration was marginally lower in the first year (3.1 ± 1.6 mg/l) compared with the second year (4.1 ± 1.8 mg/l) depicting broadly a bimodal pattern in the first year and a unimodal in the following year. From February-April, magnesium content in this water body increased sharply during both the years and registered primary maxima (first year) and peak (second year) in the month of April. There was then equally sharp decline till May

during both the years and minima was recorded in June in first year. Further, during the first year of the study secondary maxima was recorded in July (3.81 mg/l) following which there was generally low magnesium content during the paddy and post-paddy seasons.

Sodium: Sodium was found to be generally low at all the study sites and ranged between 1.17-6.68 mg/l (3.54 ± 1.58 mg/l) in the pond, 2.0-6.8 mg/l (4 ± 1.48 mg/l) in the peat bog and with relatively wider range and higher mean between 1.0-8.35 mg/l (4.46 ± 1.9 mg/l) in paddy-field during the study period. In the pond, there were marginal variations in sodium concentration between the two years with relatively narrow range of 1.17-5.0 mg/l (3.00 ± 1.19 mg/l) in the first year and 2.2-6.68 mg/l (4.09 ± 1.78 mg/l) in the second year. Further, its concentration depicted, clearly in the first year and broadly in the second year, trimodal patterns of monthly variations. It depicted primary maxima and peak in February during the two annual cycles respectively followed by a gradual decrease in sodium content till June in the first year and till May in the second year. However in the first year, it further increased gradually till August and depicted the tertiary maxima (4.34 mg/l) and the same was depicted in June (3.7 mg/l) in the second year of the study. In the first year, sodium concentration declined till November but increased again in December to attain the secondary maxima (4.7 mg/l). This was followed by a drastic drop in sodium concentration in January depicting minima of the study period. In the second year, secondary maxima (6.8 mg/l) was registered in November followed by a sharp decline during December and January as in the first year.

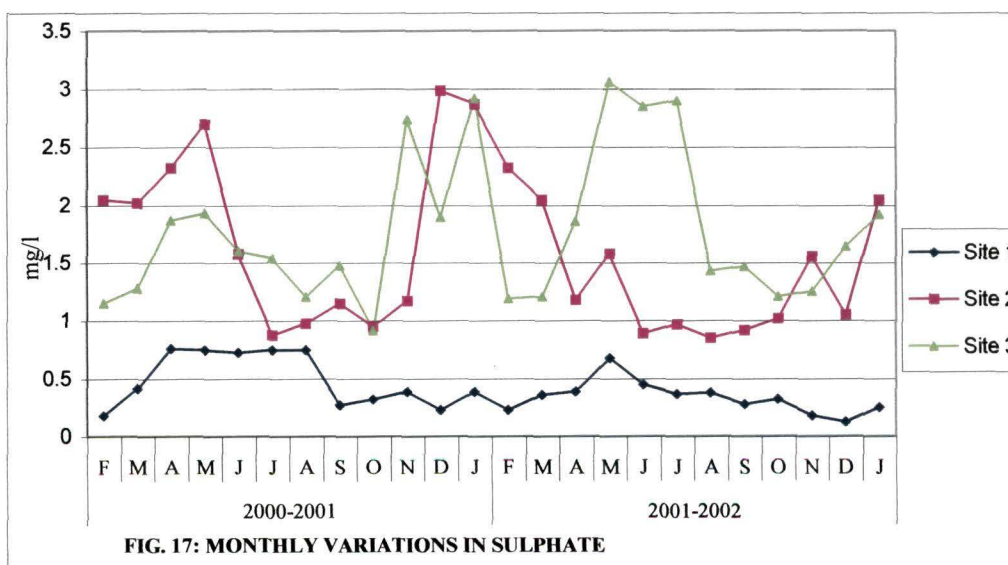
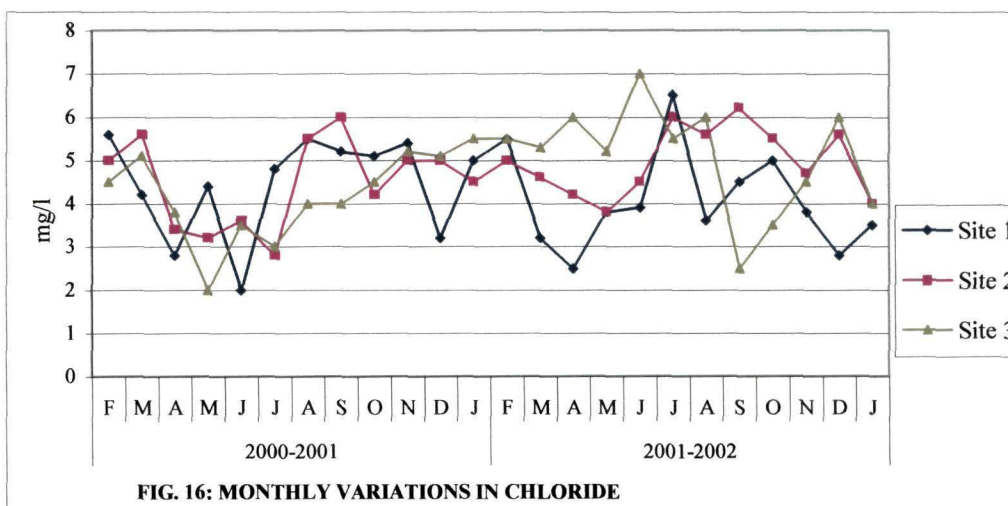
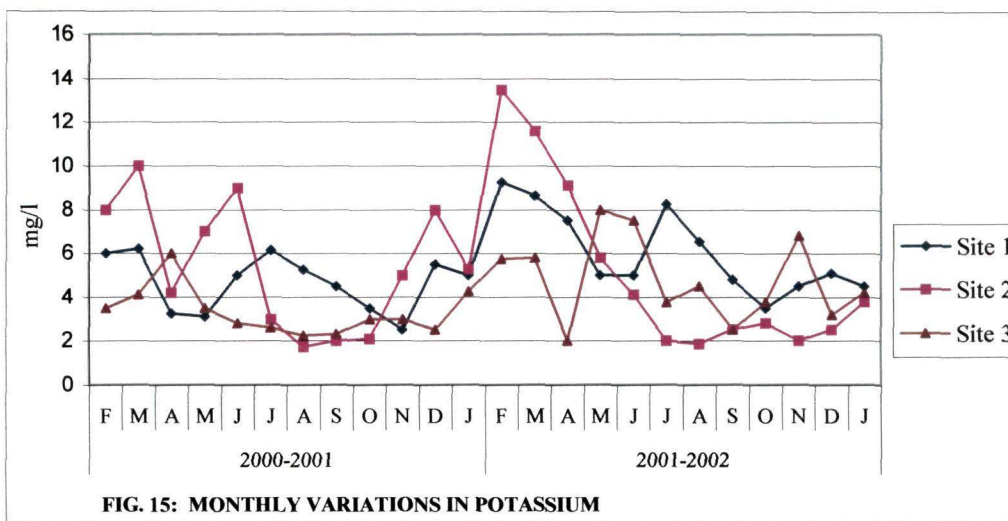
In the peat bog (Site 2), marginally higher mean value of sodium was recorded in the second year (4.55 ± 1.47 mg/l) of the study period. In addition, a unimodal pattern of monthly fluctuation of sodium content was seen during the first year and a bimodal pattern in second annual cycle. Its concentration remained relatively high during the dry months and post monsoon period with maxima (6.2 mg/l) recorded in March in the first year and the peak (6.25 mg/l) in November during the second year. Sodium content, however, decreased sharply and remained low from April-July during the study period.

In the paddy-field, even though the mean values remained identical during two years, it ranged more widely in second year (1.00-8.35 mg/l) with broadly a trimodal pattern. On the other hand, narrow range (1.67-6.84 mg/l) with a bimodal pattern of fluctuation was registered in the first year. Sodium content sharply increased from February

and resulted in secondary maxima in March (6.2 mg/l) while it dropped marginally till May. There was, however, gentle increase once again and primary maxima was recorded in August which, in turn, was followed by sharp decline until October and a gradual rise till January. However in the second year of study, peak value was recorded in February after which there were little variations in sodium concentrations till May. Its content declined sharply (minima) in June and recorded an increase again resulting in secondary maxima in August (5.2 mg/l). Even though constant fluctuations occurred from September onwards, there was progressive increase and tertiary maxima (4.67 mg/l) was registered in December.

Potassium: Potassium content during the study period was found to be generally moderate at all three sites (Fig. 15). Its monthly concentration fluctuated with narrow ranges in the pond and the paddy-field between 2.5-9.25 mg/l (5.36 ± 1.74 mg/l) and 2.0-8.0 mg/l (4.06 ± 1.72 mg/l) respectively and followed relatively wider range in the peat bog between 1.75-13.5 mg/l (5.29 ± 3.45 mg/l). However, mean value in pond was identical to that of peat bog and was marginally higher than the paddy-field. Further, its potassium content was notably low during the late monsoon (September-October) at all sites during the study period.

Notable differences in ranges as well as mean values of potassium were recorded between two annual cycles in the pond (Site 1) with bimodal pattern of monthly fluctuations during both the years. It ranged between 3.1-6.2 mg/l (4.66 ± 1.28 mg/l) during the first year and relatively widely between 3.5-9.25 mg/l (6.05 ± 1.91 mg/l) in the succeeding year. After the primary maxima in April, there was a gradual decline in May followed by a gentle rise in the next two months and depicted second maxima (6.15 mg/l) in July. Potassium content declined very gradually through out the rest of the monsoon till minima was registered in November followed by a marginal increase in December to depict the tertiary maxima (5.5 mg/l). The concentration of potassium further increased from end of the first year into the second year and depicted peak in February. After a gradual decline till May, its concentration increased again and gave rise to second maxima in July (8.25 mg/l). As in the first year, potassium content reduced gradually during late monsoon until October. However, there was a rise again in December when tertiary maxima (5.1 mg/l) was registered.



In the peat bog (Site 2), monthly variations of potassium content fluctuated between 2.0-10.0 mg/l (5.44 ± 2.91 mg/l) and 1.75-13.5 mg/l (5.29 ± 3.45 mg/l) during two years respectively depicting a trimodal pattern in the first year and a unimodal in the succeeding year. In the first year, primary maxima was recorded in March, which was followed by a sharp decline in April and almost equal rise again during the next two months exhibiting secondary maxima (9.0 mg/l) in June. Further, the potassium content decreased and remained generally low during the monsoon till October while it gradually increased from November-December and tertiary maxima (8.0 mg/l) was recorded in December. This was followed by a marginal decrease during January and subsequent peak in February. Further, it recorded a gradual decline from March-July, remained low till the end of the monsoon and increased marginally during December-January.

In the paddy-field (Site 3), potassium concentration ranged between 2.25-6.0 mg/l (3.32 ± 1.07 mg/l) and 2.0-8.0 mg/l (4.81 ± 1.95 mg/l) in two years respectively with a bimodal pattern in the first year and a trimodal during the following annual cycle. In the first year, primary maxima was recorded in April and it declined gradually till August (1.75 mg/l). After a marginal increase during the next five months a secondary maxima (4.25 mg/l) was recorded in January. In the second year, a secondary maxima of marginally higher magnitude was recorded in March (5.8 mg/l), which, in turn, was followed by a sharp decline during April and a sharp increase resulting in peak in May. Further, it recorded a steady decline during paddy season followed by an increase and secondary maxima (6.8 mg/l) in November.

Chloride: Chloride content in all the three study sites was found to be generally low (Fig. 16); it ranged between 2.5-6.5 mg/l (4.24 ± 1.15 mg/l) in the pond, 2.8-6.2 mg/l (4.73 ± 0.94 mg/l) in the peat bog and between 2.0-7.0 mg/l (4.63 ± 1.21 mg/l) in the paddy-field. In the pond (Site 1), identical ranges and mean values of chloride were observed during the two years of study period with a multimodal pattern of its temporal variations in the first year and a trimodal in the second year and relatively higher values during the rainy season. During the first year, maxima was recorded in February, which was followed by a sharp decline during April (minima) and constant fluctuations during May-January. However in the second year, chloride content declined from February-April and increased steeply to

attain peak in July. Chloride content then first declined and fluctuated regularly depicting tertiary maxima in October.

In the peat bog (Site 2), this halide showed a bimodal pattern in first year and broadly trimodal pattern in the second year. Chloride was found to be relatively higher during late monsoon (August-September) at this study site. After secondary maxima in March, the chloride content reduced and remained low during the early monsoon. Even though it increased marginally in September (primary maxima), the concentration decreased further and remained generally low (4.2-6.0 mg/l) till the end of the first year. During second year, after tertiary maxima (5.0 mg/l) in February, Chloride content dropped gradually till May (3.8 mg/l) and further increased till September depicting the peak (6.2 mg/l), which, in turn, was followed by secondary maxima (5.6 mg/l) in December.

Mean chloride concentration was slightly higher in the second year in the paddy-field (5.1 ± 1.25 mg/l) depicting broadly a multimodal pattern of monthly fluctuations. In the first year of the study, it sharply declined from a maxima in March to a minima in May. A gradual increase was seen during the paddy and the post paddy seasons. The peak value of chloride was seen in June in the second year after which it dropped sharply in September (2.5 mg/l) and then recorded a maxima during December (6.0 mg/l).

Sulphate: Sulphate concentrations fluctuated with a narrow range and low mean at Site 1 (pond) i.e., between 0.12-0.76 mg/l (0.41 ± 0.21 mg/l) and showed relatively wider ranges and higher mean values at Site 2 (peat bog) and Site 3 (paddy-field) i.e., between 0.85-2.99 mg/l (1.59 ± 0.69 mg/l) and 0.92-3.059 mg/l (1.77 ± 0.65 mg/l) respectively. Generally lower sulphate concentration was registered during September-October at all the sites.

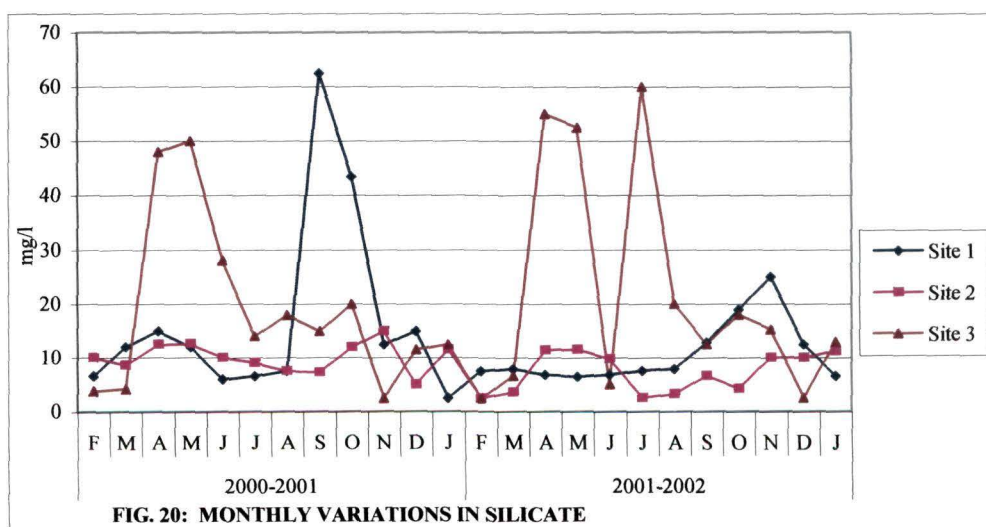
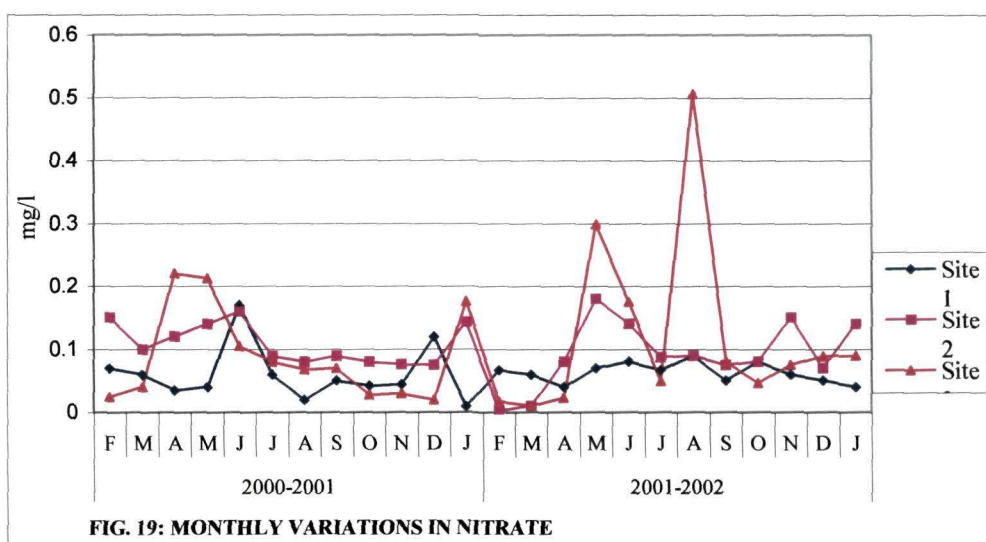
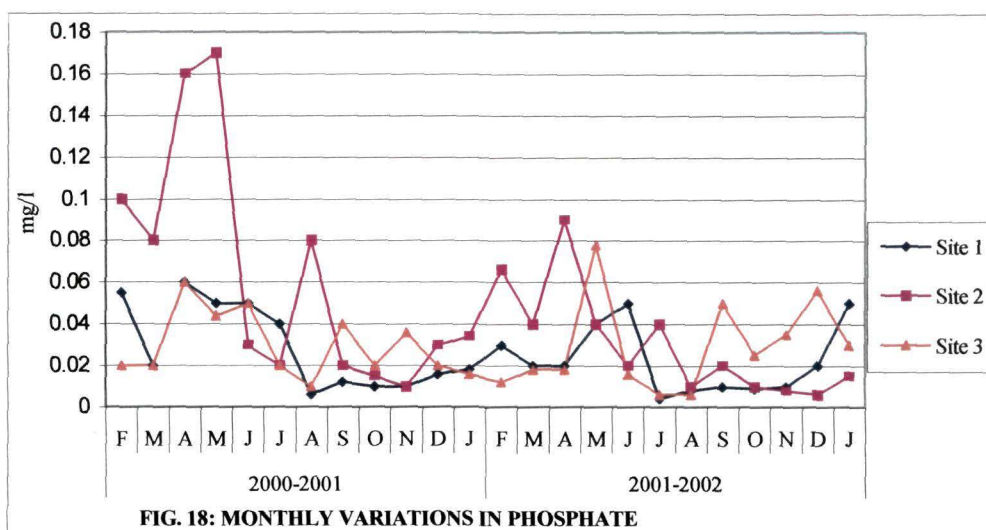
Sulphate content was generally higher during pre-monsoon period and early part of the monsoon in the pond (Site 1). During the first year, the period between February-August showed higher values depicting the peak in April. After a slight decline in September, it fluctuated marginally till February. However in the second year of the study, sulphate gradually increased and a maxima was recorded in May (0.68 mg/l). It further continued to decline and depicted minima (0.12 mg/l) in December. With a distinct bimodal pattern of temporal variations in the first year and a broadly multimodal in the second year, the sulphate concentration was found to be generally low from June-October (0.85-1.58 mg/l) at Site 2. In this ecosystem the sulphate content increased from March-May and

attained secondary maxima (2.7 mg/l) in May during the first year but in second year, it first declined from February-April and increased again marginally and exhibited secondary maxima in May (1.58 mg/l). Sulphate content remained low during the monsoon and it increased during November-December and depicted the peak in December during first year of the study. However during the second year, a tertiary maxima was recorded in November (1.56 mg/l) while primary maxima was seen in January 2002 (2.05 mg/l).

In the paddy-field (Site 3), ranges varied marginally between the first (0.92-2.92 mg/l) and the second year (1.19-3.06 mg/l) with the mean values remaining identical. It depicted broadly a trimodal pattern in the first year and a bimodal in the second year with sulphate concentration in this ecosystem remaining generally higher during pre-paddy and post-paddy seasons. With gradual increase in sulphate concentration from February-May, a secondary maxima (1.93 mg/l) was recorded while the minima was registered in October after the monsoon. Thereafter, it increased sharply again during November and registered secondary maxima (2.74 mg/l) followed by a sharp decline in December. However, sulphate concentration at this site increased again in January and culminated to primary maxima (2.92 mg/l). On the other hand, it declined marginally during February-March but it increased sharply again and depicted the peak in May (3.06 mg/l) during the second annual cycle.

Phosphate: Phosphate content at all sites was generally low (Fig. 18) with very narrow ranges and low mean values at Site 1 (pond) and at Site 3 (paddy-field) i.e., between 0.004-0.06 mg/l (0.03 ± 0.02 mg/l) and 0.006-0.078 mg/l (0.02 ± 0.02 mg/l) respectively. However at Site 3 (peat bog), relatively wider range with higher mean of phosphate concentration was depicted which ranged between 0.006-0.17 mg/l (0.05 ± 0.05 mg/l) during the study period. The phosphate concentration was found to be low during mid-monsoon at all the sites and attained peaks just prior to monsoon.

In the pond (Site 1), a marginally higher mean (0.03 mg/l) was noticed during the first year and it followed a broadly unimodal pattern of monthly variations with peak in April. Phosphate, however, decreased gradually between May-June and reduced further during the monsoon between August-November (0.004-0.01 mg/l) during the study period. It further increased gradually from December-February during the first year and up to January during the second year of the study. However, a bimodal pattern was observed



during the second year of study with maxima during June 2001 and January 2001. In the peat bog (Site 2), significantly wider range and higher mean i.e., between 0.01-0.17 mg/l (0.06 ± 0.06 mg/l) during the first year and a narrow range of 0.006-0.066 (0.03 ± 0.03 mg/l) in the second year was registered with bimodal and trimodal patterns of its temporal variations in two annual cycles respectively. A distinct peak was recorded in May during the first year and secondary maxima (0.08 mg/l) in August. The period between September-November depicted low value followed by increase till February in the second year of the study. After a slight decrease in its concentration during March, there was an increase again depicting a maxima in April followed by two maxima in July (0.04 mg/l) and in January (0.015 mg/l).

In the paddy-field (Site 3), there were no significant differences between two annual ranges and mean values of phosphate and a trimodal pattern of monthly fluctuation was noticed during the study period. Primary maxima (0.06 mg/l) was registered in April in the first year followed by gradual decline in the phosphate content during the early part of the paddy season. A marginal increase during September and November depicted secondary (0.04 mg/l) and tertiary (0.036 mg/l) maxima respectively. In the second year, peak was recorded in May and remained low from June-August as in the first year. Phosphate concentration further increased and registered two maxima in September (0.05 mg/l) and December (0.056 mg/l).

Nitrate: Nitrate content (Fig. 19) was low at all three sampling sites during the study period with narrow range of 0.009- 0.17 mg/l (0.06 ± 0.03 mg/l) in the pond (Site 1) and 0.003-0.18 mg/l (0.10 ± 0.04 mg/l) in the peat bog (Site 2). However in the paddy-field (Site 3), a relatively wider range of 0.01-0.506 mg/l (0.1 ± 0.11 mg/l) was recorded.

A relatively wider range of nitrate i.e., between 0.009-0.17 mg/l in the first year and between 0.04-0.09 mg/l in the second year were recorded at Site 1 but mean values remained identical. With a bimodal pattern of their monthly fluctuations, the nitrate concentration from February-May remained low and indicated sharp increase in June (peak). It fluctuated in the ensuing months and depicted secondary maxima (0.119 mg/l) in November, while it resulted in minima (0.009 mg/l) in January. However, nitrate remained generally low during the second year with minor fluctuations depicting roughly a multimodal pattern of their temporal variations in this water body.

At Site 2 (peat bog), no significant variations in nitrate content were noticed between the two annual cycles. There was a steady increase from March-June in the first year showing primary maxima (0.16 mg/l) in June. The concentration decreased from July-August, remained constantly low till December and increased subsequently to secondary maxima (0.143 mg/l) in January. In the second year of study, it sharply declined and registered minima in February and gradually increased and attained peak (0.18 mg/l) value during May. A gradual decline and generally a low value was seen during the monsoon till October while it registered a secondary maxima (0.15 mg/l) during November.

At Site 3 (paddy-field) nitrate content ranged between (0.1-0.22 mg/l) during first year and relatively more widely in second year (0.01-0.506 mg/l) and indicated bimodal pattern of monthly fluctuations. Further, nitrate concentration during the paddy season was found to be low particularly after September. It however gradually increased from February-April in the first year attaining the primary maxima (0.22 mg/l) and dropped gradually and remained low during the paddy season till December. However in January, there was sudden increase in nitrate content to record secondary maxima (0.176 mg/l). During the second year, minima was recorded in February 2001 after which it gradually increased and attained secondary maxima (0.298 mg/l) in May. Thereafter, a sudden drop in nitrate occurred during the next two months followed by a sharp increase again culminating into peak (0.506 mg/l) in August.

Silicate: The concentration of silica indicated wider fluctuations (Fig. 20) and ranged between 2.5-62.5 mg/l (13.66 ± 13.37 mg/l), 2.5-62.5 mg/l (16.79 ± 17.82 mg/l) and 2.5-60.0 mg/l (20.4 ± 18.4 mg/l) respectively.

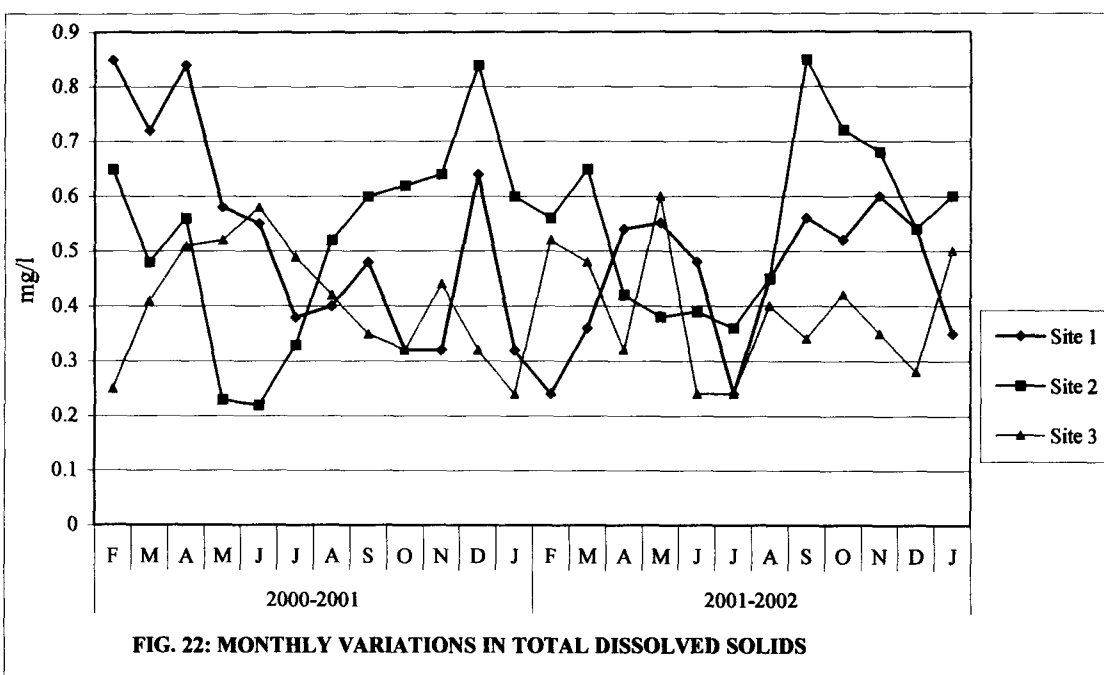
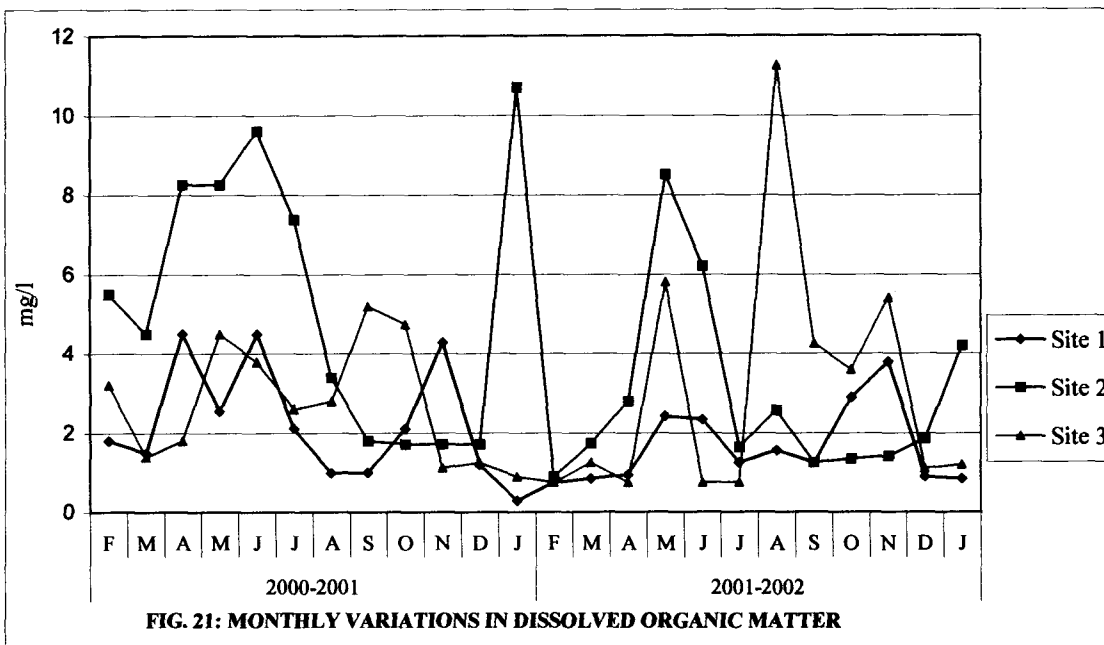
A wide variation in ranges and mean values of monthly variations in silicate was observed between the two years at Site 1. It ranged more widely between 2.5-62.5 mg/l (16.79 ± 17.82 mg/l) in the first year and between 6.5-18.9 mg/l (10.53 ± 5.90 mg/l) in the second year and depicted unimodal pattern of monthly fluctuations during both the annual cycles. Further, the silica remained significantly low from February-August and depicted maxima during late monsoon in both the years. In the first year of the study, the peak was registered in September and it decreased sharply remaining low during the post-monsoon months with minima recorded in January. During second year, maxima was registered in November with low silica concentration during pre-monsoon and monsoon periods. At Site

2, silicate content remained low throughout the study period with marginally higher mean in the first year (10.08 ± 0.8 mg/l) as compared to the following year (7.2 ± 3.78 mg/l). Further, monthly fluctuation of the silicate depicted a broadly trimodal pattern during first annual cycle and a multimodal pattern in the succeeding year exhibiting higher concentrations in pre- and post monsoon seasons. Peak silicate content was recorded in November during the first year and minima (2.5 mg/l) in February and July in the second year.

At Site 3, silica concentration fluctuated with a relatively narrow range and low mean between 2.5-50.0 mg/l (8.96 ± 15.8 mg/l) during the first year and between 2.5-60.0 mg/l (21.9 ± 21.3 mg/l) during the second year but depicted unimodal patterns and bimodal during two annual cycles respectively. Further, during first year the silicate content increased gradually from February-May, recorded maxima (50.0 mg/l) in May, declined during paddy season and recorded minima in November. Silicate concentration continued to remain low throughout winter till April during the second year. It however, increased from May-July and depicted peak (60.0 mg/l) in July, registered sharp decline again during August and fluctuated constantly till the end of the study period.

Dissolved Organic Matter: It exhibited a narrow range of 0.24-4.5 mg/l (1.95 ± 1.25 mg/l) at Site1 (pond), followed by a comparatively wider range between 0.9-10.72 mg/l (4.13 ± 3.1 mg/l) at Site 2 (peat bog) and still a wider range between 0.75-11.25 mg/l (2.92 ± 2.46 mg/l) at Site 3 (paddy-field).

In the pond, DOM exhibited relatively wider range of 0.3-4.5 mg/l (2.24 ± 1.45 mg/l) with a trimodal pattern of their monthly variations in the first year. It however, fluctuated less widely between 0.75-2.42 mg/l (1.65 ± 0.99 mg/l) with bimodal pattern during the second year of the study. Its content declined during the monsoon particularly between July-September and peak value (4.5 mg/l) was registered in April and June. It attained secondary maxima (4.28 mg/l) during November, which was followed by a sharp decline in January (minima). During the second year, relatively smaller secondary maxima was noticed during May (2.42 mg/l), which was followed by a gradual decrease till September. DOM content increased again from October and registered maxima (2.42 mg/l) in November.



In the peat bog (Site 2), DOM exhibited identical ranges during both the years but with a higher mean of 5.38 ± 3.76 mg/l in first year and 2.87 ± 2.32 mg/l in the second year and depicted a bimodal pattern of temporal variations. It increased progressively during March-June during the first year and from March-May during the second year. Consequently, it depicted a maxima (9.6 mg/l) of the first year in June and primary maxima (8.5 mg/l) of the second year in May. DOM content was, however, low during monsoon till December. Further, it registered peak (9.6 mg/l) in January during the first annual cycle.

In the paddy-field (Site 3), the DOM content in different months ranged more widely in second year of study between 0.75-11.25 mg/l (3.07 ± 3.21 mg/l) but ranged between 0.90-5.21 mg/l (2.78 ± 1.52 mg/l) during the first year of the study. Further a bimodal pattern was observed during the first year and broadly a trimodal in the second year. During the first annual cycle, DOM increased gradually from March-May to attain secondary maxima (4.5 mg/l). It declined gradually till August, which was followed by an increase to primary maxima in September. DOM continued to decline from the end of the first year till April (minima) during the second year, increased sharply to secondary maxima (5.3 mg/l) in May. With minor fluctuation during June-July, DOM further increased to its peak in August. Further, it declined during September-October but it increased in November while it remained low (1.1-1.2 mg/l) during the last two months.

Total Dissolved Solids: Total Dissolved Solids (TDS) at all the study sites was found to be very low with monthly fluctuations during the study period ranging between 0.24-0.85 mg/l (0.49 ± 0.17 mg/l) in the pond, 0.22-0.85 mg/l (0.54 ± 0.17 mg/l) in the peat bog and 0.24-0.60 mg/l (0.4 ± 0.11 mg/l) in the paddy-field.

In the pond (Site 1), there was a marginal difference in annual ranges of monthly TDS values, which ranged between 0.32-0.85 mg/l during the first year and between 0.24-0.56 mg/l in second year with multimodal patterns of fluctuations. After a peak in February (Fig. 22), minor fluctuations were observed till June, the period between July-November exhibited generally a low TDS (0.32-0.84 mg/l) but it increased sharply and depicted the secondary maxima in December (0.64 mg/l). However, during the second year, minima was recorded in February and gradually increased and depicted maxima (0.55 mg/l) in May. TDS decreased during June-July and increased gradually with minor fluctuations till the end of the study period. At Site 2 (peat bog), there was no notable difference in ranges and

mean values between the two years. Further, a bimodal pattern of monthly fluctuations of TDS was recorded during the study period. At this site, secondary maxima (0.65 mg/l) was recorded in February, and there was a gradual decline till June (minima) that, in turn, was followed by a gradual increase till maxima (0.84 mg/l) was attained in December. During the second year, TDS declined between April-August (0.38-0.45 mg/l) and increased abruptly again and registered peak (0.85 mg/l) in September and subsequently declined gradually till the end of the study period.

In case of the paddy-field (Site 3), annual ranges and mean values of TDS were identical and depicted a broadly bimodal pattern in the first year and a multimodal in the second year. There was a gradual increase from February-June when primary maxima (0.58 mg/l) was recorded. TDS, however, declined during the paddy season till October, showed a small maxima (0.44 mg/l) in November and recorded a decline during January. During the second year, TDS increased sharply during February and attained maxima (0.52 mg/l) and declined during the next two months while it sharply increased subsequently to its peak (0.60 mg/l) in May. Once again TDS value in the paddy-field declined during June-July (0.24 mg/l), fluctuated continuously throughout the paddy and the post paddy seasons and a small maxima was recorded in January (0.50 mg/l).

II. ECOLOGICAL CORRELATIONS (ABIOTIC FACTORS)

The coefficient of correlation (r) computed among various abiotic factors at three selected ecosystems viz. pond (Site 1), peat bog (Site 2) and paddy-field (Site 3) indicated by r_1 , r_2 and r_3 and are presented in Tables 5-7 respectively. Out of 190 correlations computed at Sites 1 and 2, 45 and 56 showed significant correlations among the abiotic factors of their respective biotopes. However, at Site 3 (paddy-field), out of 170 correlations computed only 27 were significant. Further, specific conductivity, pH and sulphate shared 7 significant correlations each with other abiotic parameters at Site 1, while silicate did not depict any. Similarly at Site 2, specific conductivity registered maximum of 9 significant correlations with other parameters while water temperature, transparency, pH and total hardness registered 6 correlations each and free CO_2 did not depict any. On the other hand, while at least one significant correlation was recorded by every abiotic factor in the paddy-field, maximum significant correlations were shown by pH and magnesium (5 each).

TABLE 5: CORRELATION MATRIX (r_1) BETWEEN ABIOTIC FACTORS AT SITE 1 (POND)

	Air Temp.	Water Temp.	Rainfall	Transparency	Specific Conductivity	pH	Dissolved Oxygen	Free CO ₂	Total Alkalinity	Total hardness	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Phosphate	Nitrate	Silicate	D.O.M.	T.D.S.
Air Temp.	1.000	0.851*	0.736*	-0.591*	0.161	-0.236	-0.611*	0.508**	0.119	0.237	-0.022	0.246	-0.341	0.076	0.290	0.187	-0.337	0.111	0.234	-0.049	-0.265
Water Temp.		1.000	0.855*	-0.810*	0.369	-0.294	-0.823*	0.539*	0.314	0.045	0.118	0.046	-0.290	-0.099	0.118	0.553*	-0.094	0.181	0.093	0.344	-0.081
Rainfall			1.000	-0.784*	0.411***	-0.389	-0.778*	0.338	0.142	0.122	0.169	0.162	-0.153	0.122	0.066	0.621*	-0.013	0.128	0.008	0.051	-0.165
Transparency				1.000	-0.456***	0.179	0.648*	-0.566*	-0.470***	0.137	-0.226	0.021	0.261	0.072	0.154	-0.571	-0.150	-0.344	0.060	-0.355	0.070
Sp. Conductivity					1.000	-0.551*	-0.633*	0.096	0.146	0.250	0.820*	-0.173	0.041	0.289	-0.264	0.532*	0.395	0.508*	-0.357	0.234	-0.004
pH						1.000	0.546*	-0.024	0.100	-0.590*	-0.503**	-0.325	-0.192	-0.439***	-0.031	-0.442***	-0.465***	-0.092	0.346	0.078	-0.107
Dissolved Oxygen							1.000	-0.337	-0.221	-0.276	-0.322	-0.068	0.022	-0.149	0.029	-0.650*	-0.184	-0.245	0.081	-0.313	-0.054
Free CO ₂								1.000	0.591*	-0.035	0.017	0.034	-0.099	0.058	0.216	0.074	-0.110	-0.004	-0.041	0.172	-0.112
Total Alkalinity									1.000	-0.366	0.073	-0.417***	-0.174	-0.138	-0.370	0.202	0.069	-0.047	-0.245	0.325	0.202
Total hardness										1.000	0.271	0.729*	0.488**	0.814*	0.298	-0.134	-0.177	0.101	-0.251	-0.501**	-0.254
Calcium											1.000	-0.197	0.192	0.370	-0.396	0.346	0.329	0.517	-0.374	0.149	0.123
Magnesium												1.000	0.439***	0.621*	0.392	-0.236	-0.200	-0.116	-0.097	-0.515*	-0.439***
Sodium													1.000	0.602*	-0.110	-0.269	0.013	0.086	-0.153	-0.179	0.066
Potassium														1.000	0.046	-0.208	-0.135	0.154	-0.350	-0.570*	-0.283
Chloride															1.000	-0.134	-0.346	-0.374	0.187	-0.222	-0.400
Sulphate																1.000	0.410***	0.028	-0.263	0.413***	0.087
Phosphate																	1.000	0.173	-0.322	0.319	0.421***
Nitrate																		1.000	-0.109	0.338	0.188
Silicate																			1.000	0.051	0.012
D.O.M.																				1.000	0.346
T.D.S.																					1.000

P < 0.01 (*)

P < 0.02 (**)

P < 0.05 (***)

TABLE 6: CORRELATION MATRIX (r₂) BETWEEN ABIOTIC FACTORS AT SITE 2 (PEAT BOG)

	Air Temp.	Water Temp.	Rainfall	Transparency	Specific Conductivity	pH	Dissolved Oxygen	Free CO ₂	Total Alkalinity	Total hardness	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Phosphate	Nitrate	Silicate	D.O.M.	T.D.S.
Air Temp.	1.000	0.900*	0.675*	-0.417***	-0.570*	0.609*	0.059	-0.060	-0.342	-0.030	-0.237	-0.013	-0.379	-0.423***	0.276	-0.534*	-0.188	-0.005	-0.434***	-0.028	-0.228
Water Temp.		1.000	0.808*	-0.577*	-0.554*	0.539*	-0.189	0.013	-0.249	-0.097	-0.231	-0.094	-0.326	-0.445***	0.215	-0.633*	-0.121	0.079	-0.293	-0.020	-0.360
Rainfall			1.000	-0.660*	-0.406***	0.386	-0.293	-0.046	-0.108	-0.244	-0.549*	-0.135	-0.241	-0.267	-0.133	-0.486**	0.165	0.073	-0.148	0.184	-0.652*
Transparency				1.000	0.387	-0.484**	0.294	-0.150	-0.136	0.456***	0.391	0.399	0.221	0.489**	0.089	0.481**	0.177	-0.180	0.056	-0.194	0.368
Sp. Conductivity					1.000	-0.505**	0.043	0.053	0.456***	0.390	0.281	0.342	0.637*	0.728*	-0.464***	0.610*	0.368	0.278	0.274	0.440***	-0.210
pH						1.000	0.085	-0.125	0.034	-0.348	-0.348	-0.332	-0.436***	-0.590*	0.144	-0.360	-0.467***	0.300	-0.138	0.148	-0.124
D.Oxygen							1.000	-0.039	-0.065	0.293	0.108	0.288	-0.186	0.200	0.134	0.501**	-0.143	-0.208	-0.299	-0.061	0.323
Free CO ₂								1.000	0.300	-0.200	0.212	-0.326	0.118	-0.296	-0.159	0.096	0.309	0.148	0.136	0.151	0.048
Total Alkalinity									1.000	-0.341	-0.160	-0.373	0.225	-0.073	-0.389	0.237	0.083	0.670*	0.528*	0.554*	-0.351
Total Hardness										1.000	0.486	0.896*	0.479**	0.656*	0.277	0.193	0.011	-0.496**	-0.554*	-0.351	0.118
Calcium											1.000	0.139	0.181	0.202	0.108	0.102	-0.010	-0.085	0.105	-0.247	0.442***
Magnesium												1.000	0.479**	0.703*	0.259	0.202	0.005	-0.584*	-0.635	-0.345	0.001
Sodium													1.000	0.524*	-0.142	0.288	0.235	-0.045	-0.163	-0.013	-0.185
Potassium														1.000	-0.213	0.59*	0.367	-0.246	-0.111	0.120	-0.099
Chloride															1.000	-0.310	-0.355	-0.406	-0.553	-0.683	0.494
Sulphate																1.000	0.488	0.131	0.106	0.369	0.132
Phosphate																	1.000	0.135	0.241	0.398	-0.305
Nitrate																		1.000	0.579	0.701	-0.354
Silicate																			1.000	0.509	-0.201
D.O.M.																				1.000	-0.566
T.D.S.																					1.000

P < 0.01 (*),

P < 0.02 (**)

P < 0.05 (***)

TABLE 7: CORRELATION MATRIX (r_s) BETWEEN ABIOTIC FACTORS AT SITE 3 (PADDY-FIELD)

	Air Temp.	Water Temp.	Rainfall	Specific Conductivity	pH	Dissolved Oxygen	Free CO ₂	Total Alkalinity	Total hardness	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Phosphate	Nitrate	Silicate	D.O.M.	T.D.S.
Air Temperature	1.000	0.935*	0.658*	-0.034	0.493**	-0.392	0.008	0.103	0.128	0.401	-0.008	0.065	-0.208	-0.379	-0.084	-0.127	0.175	0.353	0.343	0.183
Water Temperature		1.000	0.567*	0.204	0.422***	-0.416***	0.105	0.210	0.321	0.354	0.208	0.072	-0.119	-0.299	0.022	-0.097	0.116	0.407***	0.153	0.133
Rainfall			1.000	0.021	0.203	-0.382	0.090	0.319	0.201	0.520*	0.021	0.301	-0.117	-0.186	0.115	0.012	0.288	0.384	0.256	0.294
Specific Conductivity				1.000	-0.088	-0.168	0.209	0.334	0.515*	0.268	0.434***	0.219	0.054	-0.058	0.246	0.058	0.123	0.377	-0.296	0.102
pH					1.000	-0.190	0.009	-0.432***	-0.496**	0.207	-0.582*	-0.332	-0.454***	-0.259	-0.050	-0.297	-0.041	-0.156	0.133	0.050
Dissolved Oxygen						1.000	-0.159	-0.090	0.019	-0.307	0.129	-0.109	0.244	0.594*	0.236	-0.174	0.390	0.039	0.247	-0.180
Free CO ₂							1.000	0.234	0.207	0.550*	0.017	-0.371	0.228	0.273	0.416***	-0.042	0.045	-0.124	-0.174	-0.305
Total Alkalinity								1.000	0.632*	0.407***	0.500**	0.353	0.284	0.144	-0.006	-0.007	0.209	0.010	0.001	0.056
Total Hardness									1.000	0.251	0.938*	0.532*	0.383	0.308	0.117	0.029	0.069	0.398	-0.203	0.169
Calcium										1.000	-0.099	0.089	0.076	-0.046	0.102	-0.018	0.257	0.025	0.212	0.159
Magnesium											1.000	0.514**	0.364	0.335	0.083	0.034	-0.022	0.401	-0.285	0.113
Sodium												1.000	0.004	-0.032	-0.322	0.025	0.043	0.195	0.002	0.541*
Potassium													1.000	0.368	0.307	0.207	0.382	0.054	0.066	0.211
Chloride														1.000	0.348	-0.343	0.099	-0.160	-0.217	-0.432***
Sulphate															1.000	0.197	0.286	0.364	-0.267	-0.104
Phosphate																1.000	0.206	0.268	0.148	0.441***
Nitrate																	1.000	0.300	0.674*	0.212
Silicate																		1.000	0.133	0.210
D.O.M.																			1.000	0.186
T.D.S.																				1.000

P < 0.01 (*)

P < 0.02 (**)

P < 0.05 (***)

III. WATER QUALITY OF AQUATIC ECOSYSTEMS

Water samples collected from diverse freshwater ecosystems (Table: 1) located at different climatic regimes of Bhutan (Fig. 1) were analysed for basic abiotic factors namely water temperature, pH, specific conductivity, total alkalinity, total hardness, calcium, magnesium and chloride. The observed parameters of these water bodies are presented in Table 8.

Water temperature at Sites 1-24 ranged between 1.1-29.5° C ($17.17 \pm 7.9^\circ$ C) with the highest temperature recorded in a sub-tropical valley in east Bhutan (29° C) and minima was observed in a glacial lake (1.1° C) at an altitude of 4250m ASL. Further eight of the studied ecosystems depicted temperatures lower than 15° C, and these include: Site 23 (1.1° C) < Site 24 (1.2° C) < Site 22 (4.0° C) < Site 13 (10.8° C) < Site 10 (10.9° C) < Site 20 (11.5° C) < Site 12 (12.5° C). Similarly Site 16 (29.5° C) > Site 9 (29.0° C) > Site 8 (26.8° C) > Site 11 (25.5° C) belonged to the category of ecosystems depicting water temperature above 25° C.

Hydrogen ion concentration (pH) recorded at sampled localities ranged between 6.17-8.29 (6.80 ± 0.50), thereby, depicted a slightly acidic-alkaline nature of waters in Bhutan. Further, 13 out of 24 studied sites recorded pH less than 6.8 depicting acidic to slightly acidic nature of their biotopes. While Site 2 (peat bog) depicted the most acidic condition (pH 6.17) among the studied ecosystems, the other water bodies with pH less than 6.5 include Site 23 (pH 6.2) < Site 6 (pH 6.24) < Site 7 (pH 6.34) < Site 24 (pH 6.38) < Site 17 (pH 6.44) < Site 11 (6.48) stated in the order of their increasing acidity. One of the water bodies viz. Site 12 (an alpine lake at 3460 m ASL) shows pH of 7.27 depicting circum-neutral nature. Similarly, three of the ecosystems viz. Site 13 (a resort pond) and Site 14 (fishery pond) with pH 7.45 each and Site 18 (a paddy-field) with pH 7.6 fall within alkaline category. Further only one site i.e., Site 5 (sewage stabilization pond) was highly alkaline (pH 8.29).

Specific conductivity ranged between 12-500 μ S/cm (72.42 ± 99.20) exhibiting generally very low ionic concentration of the sampled water bodies of Bhutan. Except the sewage pond (500 μ S/cm) and a fertilized fish-pond (132 μ S/cm), the conductivity in other 22 natural water bodies ranged between 12-119 μ S/cm (49.18 ± 36.58 μ S/cm). One of the ephemeral ponds (Site 19) located at 1850 m ASL also depicted a higher specific conductivity (119 μ S/cm). Further, Site 7 (16 μ S/cm), Site 23 (12 μ S/cm) and Site 24 (14 μ S/cm) registered very low ionic concentrations (< 20 μ S/cm). Dissolved oxygen in these

TABLE 8: PHYSICO-CHEMICAL PARAMETERS OF AQUATIC ECOSYSTEMS (SITES 1-24)

Parameter / Study Sites	1	2	3	4	5*	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Range	Mean ± SD
Air Temperature (°C)	18.4	18.2	21.2	18.5	25.2	17.5	24.9	27.4	32.0	16.9	27.6	13.2	12.1	10.2	20.0	27.5	14.8	24.5	24.6	12.5	12.0	8.0	2.0	2.2	2.0 - 32.0	18.0 ± 8.0
Water Temperature (°C)	17.2	16.4	19.7	18.7	23.3	15.4	24.6	26.8	29.0	10.9	25.5	12.5	10.8	15.4	19.3	29.5	17.5	23.2	23.1	11.5	15.5	4.0	1.1	1.2	1.1 - 29.5	17.2 ± 8.0
pH	6.91	6.17	6.75	6.66	8.29	6.24	6.34	6.68	6.6	6.73	6.482	7.27	7.45	7.45	6.94	6.56	6.44	7.6	6.66	6.72	6.81	6.92	6.2	6.38	6.17 - 8.29	6.8 ± 0.5
Sp. Conductivity (µS/cm)	33	42	53	37	500	98	16	64	29	42	18.5	31	142	132	101	26	26	42	119	26	26	84	12	14	12 - 500	71.4 ± 99.2
Dissolved Oxygen (mg/l)	5.4	3.4	7	6.47	2.4	3.84	6.4	6.8	11.2	12.8	12.2	6.4	9.2	6.56	4.8	3.5	13.2	2.3	5.2	5.2	5.6	7.2	16.0	11.0	2.3 - 16.0	7.3 ± 3.7
Free Carbon dioxide (mg/l)	7.1	19.5	5.4	3.65	9.0	8.8	2.5	3.2	7.0	5.0	3.6	3.0	4.2	2.0	4.0	5.0	7.8	4.0	6.0	20.0	6.0	9.6	6.0	5.0	2.0 - 19.5	6.55 ± 4.6
Total alkalinity (mg/l)	24.8	22.2	27.9	16.1	240.0	40.0	13.1	20.0	26.0	80.0	18.5	18.0	80.0	38.0	64.0	26.0	28.9	40.0	68.0	32.4	14.0	15.0	14.0	14.0	13.1 - 240.0	40.9 ± 47.1
Total Hardness (mg/l)	16.4	18.3	22.0	11.0	76.0	36.0	8.8	24.0	24.0	28.0	9.6	7.0	11.0	58.0	40.0	26.0	18.0	24.0	62.0	12.0	8.6	12.0	10.0	16.0	7.0 - 76.0	24.1 ± 18.3
Calcium Hardness (mg/l)	4.9	5.6	7.2	5.8	41.0	12.6	3.9	4.2	4.2	13.7	4.2	3.2	6.0	21.0	27.3	6.3	4.9	12.6	29.4	4.2	2.5	4.2	3.15	6	2.5 - 41.0	9.9 ± 10.0
Magnesium (mg/l)	2.6	3.2	3.6	1.37	8.5	5.7	1.0	4.8	4.8	3.5	1.2	0.6	1.2	9.0	3.1	4.8	3.2	2.8	7.9	1.9	1.5	1.9	1.7	2.4	0.6 - 8.5	3.4 ± 2.4
Chloride (mg/l)	4.2	4.7	4.6	2.5	42.0	11.0	2.5	8.0	5.0	5.0	3.0	2.1	3.5	9.0	11.0	6.0	4.5	11.0	14.0	4.4	4.2	6.3	4.0	4.5	2.1 - 42.0	7.4 ± 8.0

Note: 1. Sampling Sites 1, 2 and 3 are regular study sites and their mean values are indicated here.

2. * A sewage stabilization pond

ecosystems ranged between 2.3-12.8 mg/l (7.25 ± 3.69); the lowest value was recorded in a sub-tropical paddy-field at 1830 m ASL (Site 18) and highest dissolved oxygen was recorded in a glacial lake (Site 23) of eastern Bhutan. Of the 24 water bodies studied, 10 exhibited well oxygenated waters (6.56-16 mg/l) while 4 water bodies depicted dissolved oxygen < 4.0 mg/l viz. Site 18 (2.3 mg/l) $<$ Site 5 (2.4 mg/l) $<$ Site 16 (3.5 mg/l) $<$ Site 6 (3.8 mg/l), the last two sites being paddy-field at 1920 m ASL and a small man made pond at 1820 m ASL respectively in east Bhutan.

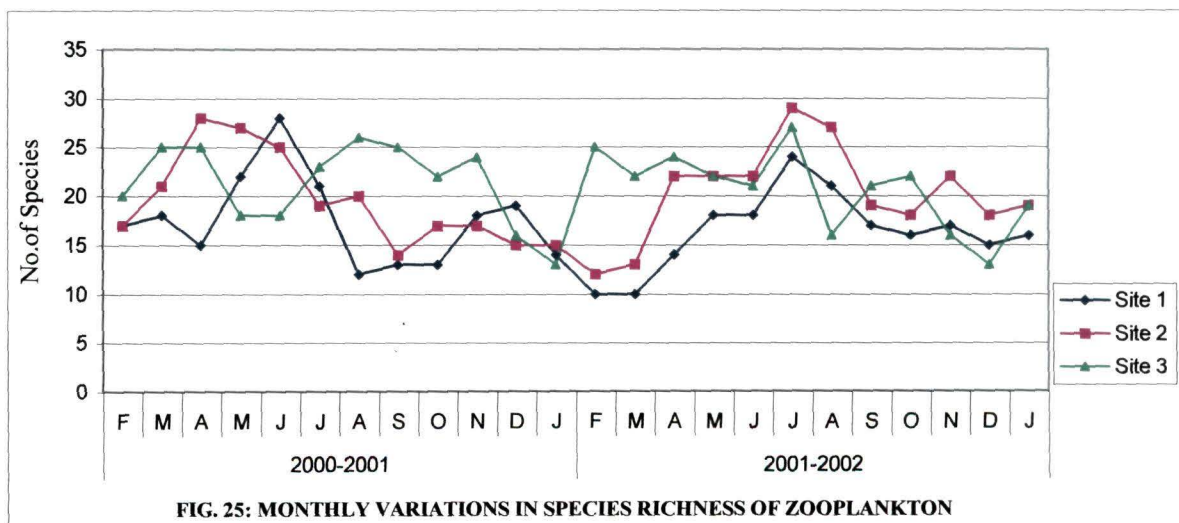
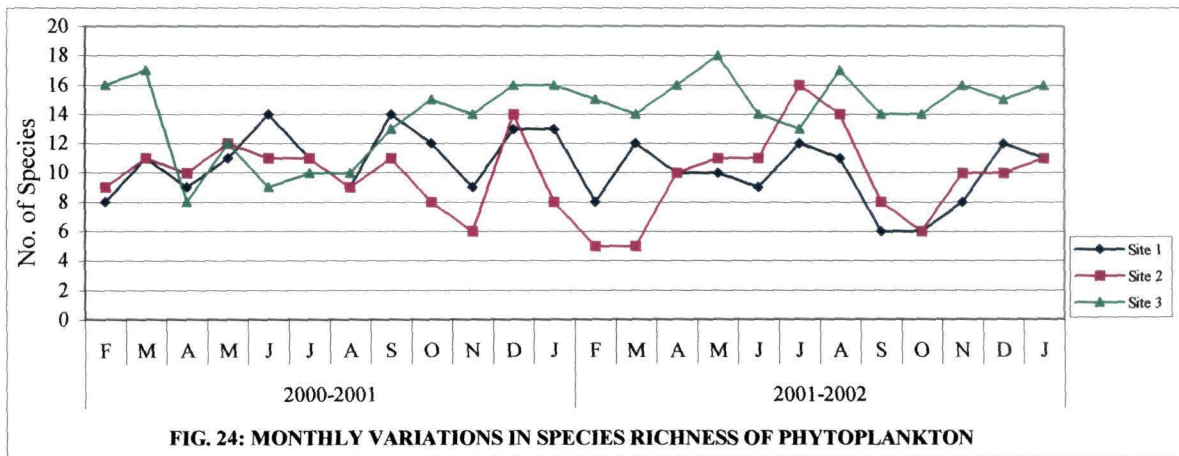
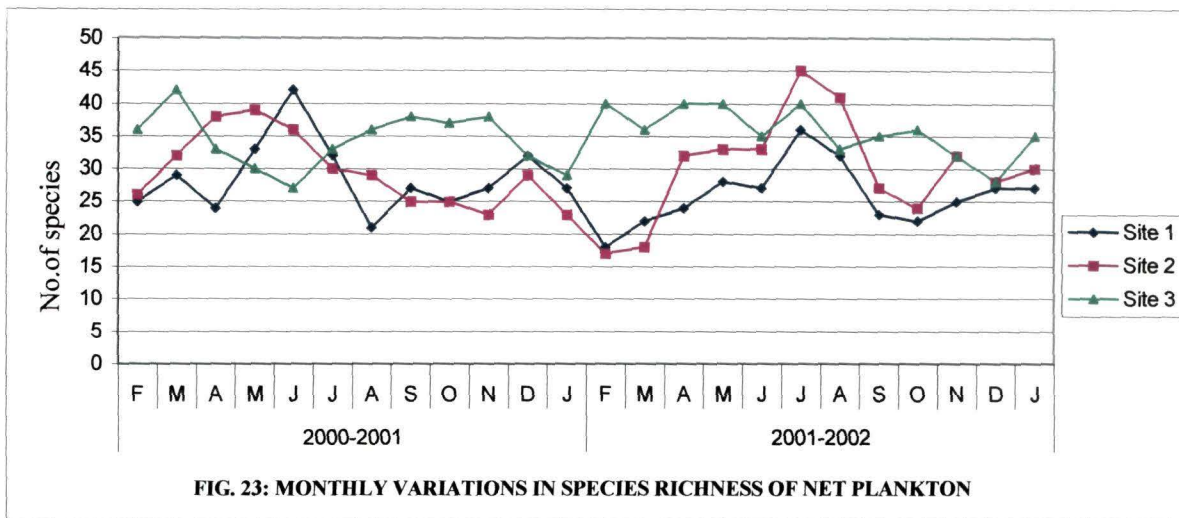
Total alkalinity at Sites 1-24 recorded wider variations i.e., between 13.1-240.0 mg/l (40.9 ± 47.0 mg/l) with highest at Site 5 (sewage stabilization pond) and lowest value was recorded at Site 7 (a paddy-field at foothills). Among the other water bodies, four sites exhibited total alkalinity of more than 50.0 mg/l. They include Site 10 (80 mg/l) = Site 13 (80 mg/l) $>$ Site 19 (68 mg/l) $>$ Site 15 (64 mg/l). Further, six water bodies depicted total alkalinity of less than 20 mg/l. They included Site 7 (13.1 mg/l) $<$ Site 21 (14 mg/l) = Site 23 = Site 24 $<$ Site 22 (15 mg/l) $<$ Site 4 (16.1 mg/l) $<$ Site 12 (18 mg/l) $<$ Site 11 (18.5 mg/l) in the stated order of their decreasing alkalinity. Similarly, total hardness ranged between 7.0-76.0 mg/l (24.11 ± 18.3 mg/l) at Sites 1-24. Maximum hardness was recorded at Site 5 and minimum at Site 12. Among the other water bodies, at Sites 14 (58 mg/l) and at Site 19 (62 mg/l) total hardness was recorded > 50 mg/l. While majority (21 sites) depicted total hardness < 50 mg/l, 12 sites depicted the hardness of < 20 mg/l. While calcium content ranged between 2.52-40.95 mg/l (9.91 ± 9.96 mg/l) at all the sites, in 23 of the water bodies (Site 5 excluded) it ranged with relatively narrow range between 2.52-29.4 mg/l (7.38 ± 6.06 mg/l). Among the other sites with high calcium content, Site 19 (an ephemeral pond at 1900m ASL) recorded 29.4 mg/l and minimum was observed at Site 21 (a pond at 2650 m ASL in east Bhutan). Similarly, magnesium ranged between 0.6-8.52 mg/l (3.42 ± 2.38 mg/l) exhibiting its low concentrations at all the sites. Further, chloride concentration ranged more widely between 2.1-42.0 mg/l (7.38 ± 8.02) at all sites and between 2.1-14 mg/l (5.73 ± 3.23) at twenty-three of the study sites (Site 5 excluded), thereby, depicting low concentration of chloride in the sampled water bodies in Bhutan.

IV. PLANKTON COMMUNITIES

A. QUALITATIVE COMPOSITION (TEMPORAL VARIATIONS)

Net Plankton: They are represented by 120 taxa of phytoplankton (47 taxa) and zooplankton (73 taxa). Their qualitative richness (Fig. 23) ranged between 18-36 species (27 ± 5 species) in the pond (Site 1), 17-45 species (30 ± 7 species) in the peat bog (Site 2) and 27-42 species (35 ± 4 species) in the paddy-field (Site 3). At Site 1 (pond), bimodal pattern during the first year and a broadly unimodal pattern of their temporal variations in second year were depicted with peak richness in June 2000 and minima in February 2001. Further, net plankton exhibited generally higher species richness from May-July during both the years. However at Site 2, broadly a unimodal pattern of temporal variations in species richness was observed during the study period. During the first year, there was gradual increase in species richness from February-May with maxima recorded in May but peak during second year was depicted in July. After a low species richness during monsoon there was marginal increase in December (29 species) in first year and during November (32 species) in second year of the study. At Site 3 (paddy-field), species richness of net plankton fluctuated with a bimodal pattern in first year and a multimodal in second year with peak in March and minima in June, both during the first year. Secondary maxima in the first year was recorded in September as well as November (38 species each). During the second year, generally high species richness was seen till October, which, in turn, was followed by marginal decrease during December (28 species).

Phytoplankton: Phytoplankton at three study sites were represented by a total of 47 species belonging to six groups viz. Chlorophyceae (20 species) > Bacillariophyceae (15 species) > Cyanophyceae (6 species) > Euglenophyceae (3 species) > Dinophyceae (2 species) > Chrysophyceae (1 species). Further, their qualitative richness among the three sites was in the order of paddy-field (35 species) > peat bog (27 species) > pond (26 species). Phytoplankton species richness at Site 1 (pond) ranged between 6-14 species (10 ± 2 species) with Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyceae. At Site 2 (peat bog), it exhibited Chlorophyceae > Bacillariophyceae > Cyanophyceae > Euglenophyceae = Dinophyceae with species richness between 5-16 species (10 ± 3 species) and at Site 3 (paddy-field), Chlorophyceae > Bacillariophyceae > Cyanophyceae > Euglenophyceae > Chrysophyceae = Dinophyceae. In this ecosystem (Site 3), species



richness ranged between 8-18 species (14 ± 3 species) with maximum numbers of phytoplankton species recorded during May in second year of the study period (Fig. 24). Minimum species richness was recorded at Site 2 during February-March in second year. Further, monthly variations in species richness of phytoplankton depicted multimodal patterns at all sites during the first year and during both the years at Site 3 (Fig. 24). However, at Site 1 a trimodal pattern in the second year was depicted with maxima in March, June and December recording equal number of species (12 species). Peak value of phytoplankton species richness (14 species) was recorded in June as well as September during the first year. While minima was recorded in September-October in the second year, March, July and December 2001 exhibited maxima of equal magnitude (12 species). At Site 2, phytoplankton richness depicted small fluctuations from February-September with primary maxima in December (14 species). However, in the second year, they followed broadly bimodal pattern with peak in July (16 species) and a secondary maxima in January (11 species). Species richness was generally low during late monsoon in both the years. At Site 3, species richness of phytoplankton was generally higher during pre-paddy season and depicted maxima in March in first year and the peak in May during second year of the study.

Among different groups of phytoplankton, Chlorophyceae with 10 species was qualitatively second important group after Bacillariophyceae at Site 1 but it was most important qualitative group at Site 2 (11 species) and Site 3 (15 species). Of the group, four taxa belonged to the filamentous algae namely, *Spirogyra* sp., *Mougeotia* sp., *Ulothrix* sp. and *Zygnema* sp. Similarly, eight species of desmids namely, *Cosmarium* sp., *Closterium* sp., *C. setaceum*, *Euastrum* sp., *Staurastrum* sp., *Micrasterias* sp., *Pleurotaenium* sp. and *Desmidium* sp. were recorded among the three sites. Further, four species of Chlorophyceae were found to occur at all the sites viz. *Cosmarium* sp., *Pleurotaenium* sp., *Pediastrum* sp. and *Spirogyra* sp. While *Staurastrum* sp. was recorded only at Site 1 (pond) in December 2001, *Pleurodiscus* sp. only at Site 2 (peat bog) and *Oedogonium* sp., *Radiococcus* sp., *Scenedesmus quadricaudata*, *Tetraspora* sp. and *Zygnema* sp. only at Site 3 (paddy-field) with occasional occurrence. *Spirogyra* sp. occurred in most of the monthly collections at all sites while *Netrium* sp. showed rare occurrence and was seen only in September 2000 and January 2002 at Site 2 and May 2001 at Site 3.

Bacillariophyceae was represented by 12 species at Site 1 (pond), 7 species at Site 2 (peat bog) and 11 species at Site 3 (paddy-field) constituting the most important qualitative group of phytoplankton at Site 1 and second important at Sites 2 and 3. Among the members of this group *Navicula* sp. was observed at all three study sites and was recorded in all the collections except November 2000 and February-March 2001 at Site 2. Other common species were *Pinnularia* sp., *Caloneis* sp., *Cymbella* sp., *Eunotia* sp., *Fragilaria* sp., and *Synedra* sp. occurring at all the sites occasionally. While *Amphora* sp., *Frustulia* sp., *Neidium* sp. and *Tabellaria* sp. were found only at Site 1 (pond), *Stauroneis* sp. was recorded only at Site 3 (paddy-field).

Cyanophyceae was represented by 6 species among which three species were common to all the three study sites, viz. *Oscillatoria* sp. which was recorded during most of the monthly collections, followed by *Phormidium* sp. and *Microcystis* sp. which occurred less frequently at all the sites. *Anabena* sp. and *Lyngbya* sp. were recorded only in the peat bog and occurred during warmer months from March-September and *Nostoc* sp. was recorded only in the paddy-field during the second year only (May and November-January). The other group of phytoplankton was Euglenophyceae, which was represented only by occasional occurrence of *Euglena* sp. in the pond. While in the peat bog, two species of this genera viz. *Euglena* sp. and *E. acus* occurred frequently, in the paddy-field they were represented by 3 species viz. *Euglena* sp., *E. acus* and *Phacus* sp. showing occasional occurrence. Further, *Ceratium* sp. at Site 2 recorded during December 2000 and February-March 2001, and *Glenodinium* sp. at Site 2 (April-May 2000) and at Site 3 (May 2001) were representative species of Dinophyceae. Chrysophyceae was represented by *Cryptomonas* sp. only and was recorded between December 2000-February 2001 and June 2001 at Site 3 (paddy-field) only.

Percentage community similarity between phytoplankton species (Tables: 9-11) ranged between 21.1-100% at Site 1 (pond), with maximum similarity observed between the months of September and October 2001 and minimum between November and April 2001. At Site 2 (peat bog), phytoplankton similarity ranged broadly between 13.3-95.2% with maximum values between April and May 2001 and minimum between April 2000 and February 2001. At Site 3 (paddy-field), it ranged less widely between 24.0-87.5% with maximum similarity between November 2001 and January 2002 and minimum between March and April 2000 as well as August and February 2001. Further at Site 1, higher

TABLE 9: PERCENTAGE SIMILARITIES OF PHYTOPLANKTON AT SITE 1 (POND)

	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
F	-	63.2	70.6	52.6	36.4	31.6	23.5	27.3	50.0	47.1	47.6	47.6	62.5	60.0	44.4	66.7	58.8	60.0	52.6	57.1	57.1	87.5	60.0	73.7
M		-	80.0	54.5	56.0	36.4	30.0	32.0	43.5	40.0	41.7	33.3	73.7	69.6	38.1	66.7	50.0	52.2	36.4	35.3	47.1	52.6	52.2	36.4
A			-	60.0	52.2	30.0	33.3	26.1	28.6	22.2	27.3	36.4	58.8	57.1	52.6	52.6	55.6	57.1	50.0	40.0	40.0	58.8	47.6	50.0
M				-	72.0	36.4	40.0	40.0	34.8	40.0	33.3	41.7	31.6	43.5	76.2	85.7	70.0	52.2	36.4	35.3	47.1	42.1	52.2	36.4
J					-	64.0	43.5	42.9	38.5	43.5	51.9	44.4	36.4	38.5	66.7	66.7	78.3	53.8	48.0	50.0	40.0	45.5	53.8	40.0
J						-	70.0	56.0	60.9	70.0	58.3	41.7	31.6	34.8	38.1	38.1	50.0	60.9	54.5	47.1	47.1	42.1	34.8	45.5
A							-	69.6	47.6	55.6	36.4	54.5	35.3	47.6	42.1	42.1	55.6	57.1	60.0	53.3	53.3	35.3	28.6	40.0
S								-	69.2	60.9	66.7	59.3	36.4	61.5	33.3	41.7	43.5	53.8	56.0	40.0	40.0	36.4	46.2	48.0
O									-	76.2	80.0	64.0	50.0	58.3	36.4	45.5	47.6	66.7	69.6	66.7	66.7	60.0	50.0	60.9
N										-	54.5	63.6	47.1	57.1	21.1	31.6	44.4	57.1	70.0	66.7	66.7	58.8	38.1	60.0
D											-	61.5	38.1	48.0	43.5	43.5	45.5	56.0	66.7	63.2	63.2	57.1	48.0	58.3
J												-	38.1	64.0	52.2	52.2	45.5	56.0	66.7	52.6	52.6	47.6	48.0	75.0
F													-	80.0	33.3	44.4	47.1	70.0	63.2	57.1	57.1	62.5	50.0	52.6
M														-	36.4	54.5	47.6	75.0	78.3	55.6	55.6	50.0	41.7	69.6
A															-	80.0	73.7	54.5	38.1	37.5	37.5	55.6	72.7	57.1
M																-	84.2	63.6	47.6	50.0	50.0	55.6	63.6	47.6
J																	-	66.7	50.0	66.7	66.7	70.6	66.7	50.0
J																		-	87.0	66.7	66.7	60.0	50.0	60.9
A																			-	70.6	70.6	52.6	43.5	63.6
S																				-	100.0	71.4	44.4	47.1
O																					-	71.4	44.4	47.1
N																						-	70.0	73.7
D																							-	60.9
J																								-

TABLE 10: PERCENTAGE SIMILARITIES OF PHYTOPLANKTON AT SITE 2 (PEAT BOG)

	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
F	-	70.0	63.2	66.7	70.0	70.0	66.7	60.0	58.8	40.0	52.2	47.1	57.1	42.9	73.7	70.0	70.0	64.0	69.6	70.6	66.7	73.7	73.7	60.0
M		-	66.7	69.6	63.6	63.6	60.0	54.5	63.2	47.1	64.0	52.6	50.0	50.0	85.7	81.8	72.7	66.7	64.0	63.2	58.8	85.7	76.2	63.6
A			-	90.9	66.7	57.1	63.2	66.7	44.4	37.5	41.7	44.4	13.3	26.7	80.0	76.2	66.7	61.5	58.3	66.7	62.5	60.0	70.0	47.6
M				-	78.3	69.6	57.1	69.6	50.0	44.4	53.8	50.0	23.5	35.3	81.8	78.3	69.6	64.3	61.5	70.0	66.7	63.6	72.7	52.2
J					-	81.8	70.0	72.7	52.6	47.1	56.0	52.6	25.0	37.5	66.7	72.7	72.7	59.3	56.0	63.2	58.8	66.7	76.2	54.5
J						-	90.0	72.7	52.6	47.1	56.0	52.6	25.0	37.5	66.7	72.7	72.7	66.7	64.0	73.7	58.8	66.7	66.7	54.5
A							-	70.0	47.1	40.0	43.5	47.1	14.3	28.6	63.2	70.0	70.0	64.0	52.2	70.6	53.3	63.2	52.6	40.0
S								-	52.6	58.8	32.0	42.1	25.0	37.5	66.7	72.7	72.7	66.7	64.0	84.2	70.6	57.1	66.7	63.6
O									-	57.1	63.6	75.0	30.8	46.2	55.6	63.2	73.7	66.7	72.7	50.0	71.4	66.7	55.6	73.7
N										-	40.0	42.9	36.4	54.5	50.0	47.1	47.1	45.5	40.0	42.9	50.0	50.0	50.0	47.1
D											-	63.6	42.1	52.6	58.3	56.0	64.0	60.0	57.1	45.5	40.0	66.7	66.7	64.0
J												-	15.4	30.8	55.6	52.6	63.2	50.0	54.5	50.0	57.1	55.6	44.4	73.7
F													-	80.0	26.7	25.0	25.0	28.6	31.6	30.8	36.4	40.0	40.0	37.5
M														-	40.0	37.5	37.5	28.6	31.6	46.2	54.5	53.3	53.3	50.0
A															-	95.2	85.7	76.9	75.0	77.8	75.0	80.0	70.0	57.1
M																-	90.9	81.5	72.0	73.7	70.6	76.2	66.7	54.5
J																	-	81.5	80.0	73.7	70.6	76.2	66.7	63.6
J																		-	93.3	66.7	54.5	61.5	53.8	51.9
A																			-	72.7	60.0	66.7	58.3	56.0
S																				-	85.7	66.7	66.7	52.6
O																					-	62.5	62.5	58.8
N																						-	90.0	66.7
D																							-	57.1
J																								-

TABLE 11: PERCENTAGE SIMILARITIES OF PHYTOPLANKTON AT SITE 3 (PADDY-FIELD)

	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
F	-	66.7	50.0	57.1	64.0	61.5	46.2	69.0	77.4	66.7	68.8	75.0	64.5	60.0	68.8	64.7	53.3	55.2	72.7	73.3	73.3	75.0	64.5	75.0
M		-	24.0	41.4	46.2	44.4	37.0	53.3	62.5	58.1	54.5	60.6	68.8	71.0	78.8	51.4	58.1	66.7	70.6	51.6	58.1	60.6	75.0	66.7
A			-	70.0	58.8	55.6	55.6	57.1	52.2	36.4	50.0	41.7	26.1	27.3	41.7	46.2	36.4	38.1	32.0	54.5	45.5	50.0	34.8	41.7
M				-	38.1	54.5	54.5	56.0	59.3	38.5	50.0	57.1	44.4	38.5	57.1	53.3	53.8	48.0	41.4	53.8	61.5	64.3	44.4	50.0
J					-	73.7	73.7	63.6	66.7	52.2	56.0	56.0	33.3	43.5	40.0	37.0	34.8	45.5	46.2	60.9	43.5	56.0	50.0	48.0
J						-	70.0	60.9	72.0	50.0	53.8	61.5	48.0	33.3	46.2	42.9	50.0	43.5	44.4	58.3	50.0	53.8	48.0	53.8
A							-	52.2	64.0	58.3	53.8	53.8	24.0	25.0	38.5	28.6	50.0	52.2	44.4	58.3	50.0	53.8	48.0	46.2
S								-	85.7	59.3	75.9	69.0	50.0	59.3	62.1	58.1	44.4	53.8	60.0	74.1	74.1	75.9	42.9	69.0
O									-	75.9	83.9	83.9	66.7	55.2	71.0	60.6	62.1	71.4	68.8	82.8	82.8	83.9	60.0	83.9
N										-	66.7	60.0	48.3	42.9	60.0	43.8	57.1	66.7	64.5	71.4	71.4	66.7	62.1	66.7
D											-	81.3	64.5	53.3	56.3	58.8	73.3	69.0	66.7	86.7	80.0	68.8	45.2	75.0
J												-	77.4	60.0	68.8	64.7	66.7	69.0	72.7	73.3	80.0	75.0	64.5	81.3
F													-	69.0	64.5	60.6	62.1	57.1	68.8	55.2	62.1	58.1	53.3	71.0
M														-	60.0	56.3	50.0	51.9	71.0	50.0	57.1	53.3	48.3	60.0
A															-	70.6	60.0	75.9	72.7	66.7	73.3	81.3	83.9	75.0
M																-	50.0	58.1	68.6	62.5	62.5	76.5	60.6	64.7
J																	-	74.1	71.0	71.4	71.4	66.7	55.2	73.3
J																		-	73.3	81.5	74.1	69.0	71.4	75.9
A																			-	71.0	71.0	66.7	68.8	78.8
S																				-	85.7	80.0	55.2	80.0
O																					-	86.7	55.2	86.7
N																						-	64.5	87.5
D																							-	71.0
J																								-

community similarity (80% and above) was recorded in other seven instances, i.e., between March and April 2000 (80%), May 2000 and May 2001 (85.7%), October and December 2000 (80%), February 2000 and November 2001 (87.5%), February and March 2001 (80%), April and May 2001 (80%) and July and August 2001 (87%). Similarly community similarity less than 30% was observed in 5 instances i.e., between February and September 2000 (27.3%), April and September 2000 (26.1%), April and October 2000 (28.6%), April and November 2002 (22.2%) and between April and December 2002 (27.3%). At Site 2, the community similarity was greater than 90% in four instances namely, between April and May 2000 (90.9%), July and August 2000 (90%), May and June 2001 (90.9%) and November and December 2001 (90%). Similarly, the percentage similarities of phytoplankton in February 2001 were less than 30% similar with eleven other months viz. April (13.3%), May (23.5%), June (25%), July (25%), August (14.3%) and September (25%) of first year and January (15.4%), April (26.7%), May (25%), June (25%) and July (28.6%) of second year. At Site 3 (Table 11), in six instances the community similarity was less than 30% i.e., between March and April 2000 (24%), April 2000 and February 2001 (26.1%), April 2000 and March 2001 (27.3%), August 2000 and February 2001 (24%), August 2000 and March 2001 (25%) and August 2000 and May 2001 (28.6%), while the phytoplankton community of October 2000 exhibited more than 80% similarity in seven instances i.e., with September (85.7%), December (83.9%) and January (83.9%) in the first year of study and September (82.8%), October (82.8%), November (83.9%) and January (83.9%) in the second year of study.

Zooplankton: They were represented by 73 taxa with Rotifera (38 species) > Cladocera (21 species) > Rhizopoda (9 species) > Copepoda (2 species) > Ostracoda (1 species) = Nematoda (1 species) = Gastrotricha (1 species) at Sites 1-3. Qualitative dominance of zooplankton species richness at three sites was in the order of paddy-field (54 species) > pond (51 species) > peat bog (49 species) during the study period. At Site 1 (pond), species richness ranged between 10-28 species (17 ± 4 species) and exhibited the following spectrum, i.e., Rotifera (22 species) > Cladocera (16 species) > Rhizopoda (7 species) > Copepoda (2 species) > Ostracoda (1 species) = Nematoda (1 species) = Gastrotricha (1 species) in the stated order of their qualitative significance. While at Site 2 (peat bog), their richness ranged between 12-29 species (20 ± 5 species) and various groups of zooplankton

as Rotifera (23 species) > Cladocera (13 species) > Rhizopoda (8 species) > Copepoda (3 species) > Ostracoda (1 species) = Nematoda (1 species). Similarly at Site 3 (paddy-field), various groups of zooplankton comprised of 13-27 species (21 ± 4 species) with Rotifera (28 species) > Cladocera (13 species) > Rhizopoda (8 species) > Copepoda (2 species) > Ostracoda (1 species) = Nematoda (1 species) = Gastrotricha (1 species). Maximum numbers of zooplankton species were recorded at Site 2 (29 species) in July during the second year and at Site 1 (28 species) and Site 3 (27 species) in June during first year. Further at Site 1, higher species richness of zooplankton was recorded in the first year (13-28 species) compared to the second year (10-24 species) and depicted a bimodal pattern of their monthly variations in the first year and a unimodal in the succeeding year (Fig. 25). Higher species richness annually was noticed during monsoon with peak in June of first year and minima in February-March in the second year of the study in this water body. At Site 2, broadly a unimodal pattern of their monthly species richness fluctuation was observed annually. It recorded its maxima in April (28 species) and July (29 species) during the two years respectively. Generally species richness in this ecosystem remained low from September-February and recorded its minima in February during the second year of the study. At Site 3, a broadly trimodal pattern of their monthly species richness in the first year and a multimodal in the second year was observed. Peak species richness (27 species) was registered in July in the second year and the primary maxima (26 species) in August of the first year. However species richness of zooplankton declined during the post-paddy season and minima was observed in January during the first year of the study in this ecosystem.

Phylum Rotifera comprised the most important qualitative group of zooplankton at all three sites and included 22 species at Site 1 (pond) of which *Lecane hornemanni*, *Mytilina ventralis* and *Platyias polyacanthus* were confined only to this site. While *Testudinella patina* occurred most frequently being absent only between July- September 2000 and December 2001, *Trichocerca pusilla* was recorded in 18 out of 24 months in this water body. Of the more rare species at this site, *Platyias polyacanthus* was recorded only during November-January and *Brachionus quadridentatus* only in April of both the years. Similarly, *Conochilus* sp. and *Lepadella ovalis* were recorded only once each during June and December 2000 respectively. At Site 2 (pond), 23 species of rotifers were listed with three species exclusively found at this site viz. *Anuraeopsis fissa*, *Dicranophorous* sp. and

Lecane doryssa. With species richness varying between 3-12 species, generally higher species richness was seen in warmer months with maximum recorded in April 2000. While *Lecane closterocerca* and *Philodina* sp. were most frequently occurring species, *Conochilus* sp., *Trichocerca longiseta* and *Trichotria tetractis* occurred only once each in the months of June 2000, April 2000 and July 2001 respectively. *Anuraeopsis fissa* was noted only in the last three months of the study period (November 2001-Januaray 2002) and *Lepadella patella* was observed only during the warmer months mostly between March-August in this peat bog. Similarly at Site 3 (paddy-field), the rotifers exhibited highest species richness (28 species) among the three sites. A bimodal pattern of monthly occurrence was observed at this site with maximum species richness in mid-monsoon with 14 species in July 2000 and 15 in August 2001 followed by second maxima in April 2000 (12 species) and February 2001 (10 species). Amongst them 5 species were recorded only at this site including *Lecane papuana*, *L. quadridentata*, *Lepadella acuminata*, *Platyias patulus* and *Trichocerca rattus*. While *Lecane quadridentata*, *Lepadella acuminata*, *Platyias quadricornis*, *Trichocerca longiseta* and *T. rattus* were recorded only in one of the monthly collections each, *Euchlanis dilatata* was seen in almost all the months except October 2001 followed by *Lecane bulla* which was recorded in almost all the months except in June and December 2001.

Cladocera was second qualitatively important group at all study sites. It was represented by 16 species at Site 1 and 13 each at Sites 2 and 3. Of the group, *Moina micrura*, *Macrothrix laticornis*, *Chydorus sphaericus*, *Pleuroxus similis*, *Alona costata*, *A. rectangula*, *A. guttata* and *A. monocantha* were recorded at all the sites. *Ceriodaphnia reticulata* was recorded in most of the monthly collections except between July-September in the first year and August-December in the second year at Site 1 (pond) and only once in May during the first year at Site 3 (paddy-field). *Scapholeberis kingi* was prevalent in warmer months mostly between April-June during both the years at Site 1, and it was recorded only once in July 2001 at Site 3. While *Alona affinis* was recorded only at Site 1, two species viz. *Diphanosoma excisa* and *Daphniopsis* sp. were recorded only at Site 2 (peat bog) between February-May. In the peat bog, generally greater species richness of cladocerans was exhibited during pre-monsoon period registering highest richness in May 2000 (9 species). Further at this site, *Biapertura karua* appeared only once in the month of September 2001, *Simocephalus serrulatus* was seen in all the months except November

2000. *Alona guttata* was recorded in all months except December 2000-March 2001 and January 2002. *Macrothrix laticornis* occurred only in June and July 2000 and July, August and November 2001. At Site 3 (paddy-field), *Alona costata* occurred in all the months followed by *Pleuroxus similis*, which was seen in almost all months except August 2000 and July 2001. *Ceriodaphnia reticulata* and *Scapholeberis kingi* occurred in single collection each only in the months of May 2000 and July 2001 respectively.

Rhizopoda, the third qualitatively important group of zooplankton at all three sites, consisted of 7 species at Site 1 with *Arcella* sp. occurring only at this site. Among the other species, *Diffugia* sp. was found in most of the months followed by *Euglypha* sp., the later being absent between May-June in both the years. Amongst occasionally appearing species, *Arcella megastoma* occurred only in this water body and was recorded only during September-December. It was followed by *Centropyxis ecornis* that occurred only from May-July. At Site 2, Rhizopoda was represented by 8 species and higher richness was noticed in mid-monsoon (July-August). Among the group, *Diffugia* sp. was present in all the months followed by *Centropyxis aculeate* and *Euglypha* sp., which were found in most of the monthly collections. Similarly, 8 species of Rhizopoda were documented during the study period in the paddy-field (Site 3). In this water body *Arcella discoides* was observed in all the monthly collections except December 2000 and *Actinospherium* sp. was seen less frequently and it was not seen from April-January in the second year of study. *Euglypha* sp. was not recorded during monsoon (June-September) in both the years but was observed in most other months in this ecosystem.

Copepoda was represented by two species each at Sites 1 (pond) and 3 (paddy-field) and by three species at Site 2 (peat bog). Of the group, *Tropocyclops* sp. was recorded at all sites and was observed in all their monthly collections. While *Eucyclops* sp. was observed at Site 1 and Site 2 occurring occasionally at both the sites, *Diaptomus* sp. was recorded only at Site 2 and occurred in three monthly collections viz. March 2000, February and March 2001. At Site 3, *Allodiaptomus* sp. was recorded between January-April of both the years. Ostracoda represented by *Cypris* sp. and a species of Nematoda occurred with irregular frequency at all sites. Similarly, Gastrotricha represented by *Chaetonotus* sp. occurred at Site 1 (in July 2001) and occasionally with irregular frequency at Site 3.

Percentage similarity between zooplankton at Site 1 (pond) ranged between 20.0-90.0% with highest between February and March 2001 and minimum between August 2000

TABLE 12: PERCENTAGE SIMILARITIES OF ZOOPLANKTON AT SITE 1 (POND)

	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
F	-	74.3	56.3	51.3	48.9	36.8	34.5	33.3	53.3	51.4	55.6	58.1	66.7	66.7	64.5	40.0	45.7	48.8	47.4	58.8	54.5	52.9	68.8	66.7
M		-	48.5	45.0	60.9	51.3	33.3	45.2	51.6	61.1	59.5	62.5	50.0	50.0	68.8	66.7	61.1	61.9	56.4	68.6	64.7	57.1	48.5	64.7
A			-	59.5	46.5	38.9	29.6	21.4	57.1	48.5	47.1	41.4	48.0	56.0	75.9	60.6	42.4	30.8	38.9	56.3	51.6	50.0	33.3	51.6
M				-	76.0	65.1	35.3	40.0	51.4	55.0	48.8	44.4	37.5	43.8	55.6	70.0	50.0	47.8	51.2	66.7	57.9	51.3	48.6	47.4
J					-	77.6	35.0	43.9	43.9	47.8	46.8	52.4	26.3	31.6	52.4	69.6	73.9	69.2	61.2	57.8	54.5	44.4	41.9	45.5
J						-	42.4	52.9	35.3	46.2	40.0	34.3	19.4	25.8	45.7	71.8	66.7	62.2	57.1	57.9	48.6	47.4	38.9	32.4
A							-	56.0	40.0	40.0	25.8	23.1	27.3	27.3	30.8	33.3	20.0	33.3	54.5	48.3	50.0	48.3	29.6	21.4
S								-	46.2	64.5	43.8	29.6	34.8	43.5	37.0	45.2	38.7	37.8	52.9	53.3	55.2	46.7	42.9	27.6
O									-	64.5	75.0	51.9	60.9	52.2	59.3	45.2	38.7	43.2	41.2	66.7	75.9	60.0	35.7	48.3
N										-	64.9	56.3	42.9	42.9	62.5	61.1	38.9	52.4	61.5	74.3	82.4	74.3	66.7	58.8
D											-	48.5	55.2	48.3	54.5	43.2	54.1	55.8	60.0	72.2	62.9	61.1	41.2	57.1
J												-	50.0	58.3	64.3	56.3	43.8	47.4	45.7	51.6	53.3	45.2	41.4	53.3
F													-	90.0	50.0	28.6	28.6	35.3	32.3	44.4	38.5	44.4	32.0	46.2
M														-	58.3	35.7	28.6	29.4	32.3	51.9	46.2	37.0	24.0	46.2
A															-	68.8	50.0	47.4	51.4	64.5	66.7	58.1	41.4	60.0
M																-	61.1	52.4	51.3	57.1	58.8	57.1	42.4	52.9
J																	-	81.0	61.5	62.9	47.1	45.7	36.4	52.9
J																		-	66.7	53.7	55.0	58.5	46.2	55.0
A																			-	73.7	59.5	63.2	44.4	48.6
S																				-	78.8	70.6	50.0	60.6
O																					-	72.7	58.1	62.5
N																						-	75.0	72.7
D																							-	64.5
J																								-

TABLE 13: PERCENTAGE SIMILARITIES OF ZOOPLANKTON AT SITE 2 (PEAT BOG)

	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
F	-	68.4	57.8	68.2	61.9	55.6	54.1	58.1	58.8	47.1	62.5	56.3	41.4	60.0	61.5	71.8	61.5	56.5	59.1	66.7	62.9	61.5	62.9	72.2
M		-	77.6	79.2	65.2	60.0	53.7	57.1	57.9	42.1	44.4	33.3	36.4	58.8	79.1	74.4	74.4	64.0	66.7	70.0	66.7	65.1	41.0	65.0
A			-	87.3	64.2	63.8	54.2	47.6	44.4	35.6	37.2	41.9	40.0	82.9	72.0	68.0	68.0	63.2	61.8	55.3	52.2	60.0	52.2	59.6
M				-	73.1	65.2	59.6	48.8	54.5	50.0	47.6	47.6	41.0	50.0	77.6	77.6	77.6	67.9	74.1	60.9	57.8	57.1	57.8	69.6
J					-	72.7	57.8	46.2	52.4	47.6	55.0	50.0	32.4	47.4	72.3	72.3	63.8	66.7	65.4	63.6	60.5	55.3	55.8	59.1
J						-	76.9	54.5	50.0	44.4	47.1	41.2	25.8	31.3	58.5	63.4	78.0	75.0	73.9	63.2	59.5	58.5	59.5	63.2
A							-	64.7	59.5	75.7	62.9	45.7	37.5	48.5	57.1	38.1	76.2	69.4	72.3	76.9	73.7	57.1	57.9	56.4
S								-	77.4	58.1	62.1	41.4	38.5	44.4	61.1	55.6	50.0	51.2	58.5	72.7	75.0	61.1	43.8	48.5
O									-	82.4	68.8	50.0	34.5	40.0	56.4	56.4	56.4	47.8	50.0	66.7	68.6	56.4	45.7	61.1
N										-	68.8	37.5	27.6	33.3	46.2	56.4	56.4	52.2	59.1	72.2	68.6	61.5	51.4	50.0
D											-	53.3	37.0	50.0	59.5	59.5	54.1	45.5	52.4	64.7	66.7	54.1	54.5	64.7
J												-	44.4	42.9	48.6	43.2	37.8	40.9	33.3	47.1	42.4	37.8	48.5	58.8
F													-	72.0	41.2	29.4	23.5	34.1	30.8	38.7	33.3	29.4	33.3	32.3
M														-	62.9	51.4	45.7	42.9	45.0	50.0	51.6	45.7	48.4	43.8
A															-	77.3	68.2	58.8	61.2	68.3	70.0	54.5	50.0	58.5
M																-	77.3	66.7	73.5	68.3	65.0	63.6	60.0	63.4
J																	-	82.4	85.7	73.2	70.0	63.6	65.0	68.3
J																		-	53.6	66.7	63.8	66.7	55.3	62.5
A																			-	73.9	75.6	69.4	62.2	60.9
S																				-	91.9	68.3	54.1	63.2
O																					-	70.0	55.6	59.5
N																						-	75.0	68.3
D																							-	64.9
J																								-

TABLE 14: PERCENTAGE SIMILARITIES OF ZOOPLANKTON AT SITE 3 (PADDY-FIELD)

	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
F	-	80.0	71.1	63.2	68.4	60.5	60.9	66.7	61.9	63.6	66.7	68.6	75.6	71.4	77.3	61.9	48.8	55.3	61.1	63.4	76.2	72.2	72.7	75.6
M		-	80.0	55.8	69.8	58.3	62.7	64.0	68.1	65.3	43.9	55.0	68.0	68.1	73.5	63.8	47.8	53.8	58.5	73.9	80.9	68.3	63.2	72.7
A			-	65.1	74.4	62.5	78.4	76.0	80.9	69.4	43.9	50.0	60.0	59.6	53.1	63.8	52.2	46.2	58.5	82.6	76.6	73.2	57.9	68.2
M				-	72.2	58.5	59.1	55.8	65.0	61.9	52.9	60.6	60.5	60.0	57.1	55.0	46.2	57.8	70.6	71.8	55.0	64.7	58.1	59.5
J					-	63.4	68.2	69.8	85.0	66.7	47.1	60.6	60.5	60.0	66.7	50.0	51.3	62.2	76.5	87.2	75.0	70.6	64.5	59.5
J						-	73.5	79.2	62.2	68.1	66.7	63.2	66.7	62.2	51.1	48.9	63.6	56.0	56.4	68.2	71.1	56.4	55.6	71.4
A							-	90.2	79.2	72.0	52.4	48.8	62.7	58.3	44.0	37.5	42.6	60.4	47.6	72.3	79.2	61.9	56.4	57.8
S								-	76.6	69.4	63.4	60.0	68.0	63.8	49.0	46.8	39.1	50.0	43.9	69.6	76.6	63.4	57.9	68.2
O									-	65.2	36.8	43.2	55.3	50.0	52.2	36.4	51.2	57.1	52.6	79.1	72.7	73.7	57.1	53.7
N										-	60.0	61.5	73.5	65.2	66.7	56.5	35.6	54.9	60.0	80.0	78.3	70.0	64.9	65.1
D											-	77.4	73.2	73.7	55.0	57.9	32.4	41.9	43.8	48.6	57.9	50.0	55.2	74.3
J												-	70.0	64.9	46.2	54.1	38.9	42.9	51.6	55.6	54.1	51.6	57.1	76.5
F													-	76.6	65.3	68.1	43.5	50.0	53.7	60.9	63.8	63.4	57.9	77.3
M														-	60.9	54.5	41.9	53.1	47.4	55.8	59.1	52.6	51.4	78.0
A															-	73.9	57.8	58.8	70.0	66.7	69.6	65.0	59.5	69.8
M																-	55.8	49.0	63.2	55.8	54.5	63.2	51.4	63.4
J																	-	66.7	64.9	52.4	51.2	43.2	41.2	50.0
J																		-	65.1	66.7	57.1	46.5	45.0	56.5
A																			-	75.7	63.2	62.5	62.1	57.1
S																				-	79.1	75.7	70.6	65.0
O																					-	73.7	68.6	73.2
N																						-	82.8	62.9
D																							-	68.8
J																								-

and June 2001 (Table: 12). At Site 2 (peat bog), it ranged between 23.5-91.9% with highest value between September and October 2001 and minimum similarity between February and May 2001 (Table: 13). At Site 3 (paddy-field), it ranged relatively less widely between 37.5-90.2% with highest similarity between August and September 2000 and minimum between August 2000 and May 2001 (Table: 14). Further, at Site 1 higher community similarity (81%) was also observed between June and July 2001 while similarity less than 30% was exhibited between several months (16 instances). Of this, the community structure of August 2000 was less than 30% similar with eight other months especially during December 2000-March 2001, December 2001 and January 2002. At Site 2, zooplankton community similarity during February 2001 was less than 30% similar with five months i.e., July (25.8%) and November (27.6%) of first year and with May (29.4%), June (23.5%) and November (29.4%) of second year. On the other hand, higher community similarity was seen between April and May 2000 (87.3%), October and November 2001 (82.4%) and June and August 2001 (85.7%). At Site 3, among 5 instances of higher community similarity (more than 80%) of zooplankton, March 2000 was found to be significantly similar with February 2000 (80%), April 2000 (80%) and October 2001 (80.9%).

B. BIODIVERSITY OF ROTIFERA

During the present study, along with regular limnological investigation at three selected ecosystems in eastern Bhutan, qualitative plankton samples were collected from several standing water bodies in Bhutan, mainly from eastern part of the country. The samples were screened for identification of rotifer fauna. Species composition of the recorded taxa in the sampled water bodies is presented in Table: 15 and illustrated (Figs. 26-106). The systematic account is briefly described below:

Phylum: Rotifera
Class: Eurotatoria Bartos, 1959
Superorder: Monogononta Wesenberg-Lund, 1889
Order: Ploimida Delage, 1897
Family: Brachionidae Wesenberg-Lund, 1889

1. *Brachionus angularis* Gosse, 1851 (Fig. 26, 86)

Characters: Lorica rigid, usually stippled and dorsoventrally compressed. Anterior occipital margin with two median spines flanked by a v-shaped sinus. Posterior spines lacking. Large foot opening and flanked laterally by cuticular protuberances.

Distribution: Bhutan - Trashigang, Mongar, Samdrup Jongkhar and Thimphu districts at Sites 3, 4, 5, 8, 9, 18 and 19

Sub-continent- India (Meghalaya, Jammu, Kashmir, Assam, West Bengal, Orissa, Bihar, Andhra Pradesh, Maharashtra, Madhya Pradesh, Delhi, Punjab and Haryana), Nepal
Elsewhere - Cosmopolitan.

2. *Brachionus bidentatus* Anderson, 1889 (Fig. 27)

Characters: Lorica firm and elongated. Anterior margin with longer lateral and median spines than intermediate ones. Postero-lateral spines almost parallel sided. Foot opening with a symmetrically projecting sheath.

Distribution: Bhutan - Samdrup Jongkhar, Sarpang and Thimphu districts at Sites 5, 9 and 14

Sub-continent- India (Meghalaya, Assam, West Bengal, Andhra Pradesh, Orissa, Punjab and Haryana), Nepal
Elsewhere - Tropics and sub-tropics.

3. *Brachionus calyciflorus* Pallas, 1766 (Fig. 28)

Characters: Lorica flexible and broadly oval in outline. Anterior occipital margin with four spines of variable lengths; median slightly longer than laterals. Postero-lateral spines present.

Distribution: Bhutan - Sarpang and Thimphu districts at Sites 5 and 14

Sub-continent- India (Meghalaya, West Bengal, Orissa, Bihar, Madhya Pradesh and Punjab, Jammu), Nepal
Elsewhere – Cosmopolitan.

4. *Brachionus patulus* (O.F. Müller, 1786) (Fig. 29, 87)

Characters: Lorica rigid, sub-rectangular and moderately compressed dorsiventrally; dorsum with reticulate areolation. Both occipital margins with short, blunt spines with median larger than the laterals. Posterior spines short. Foot opening flanked by asymmetrical spines.

TABLE 15: SPECIES COMPOSITION OF PHYLUM ROTIFERA (SITES 1-24)

Species↓ Study Sites →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
<i>Anuraeopsis fissa</i>	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ascomorpha</i> sp.	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Asplanchna priodonta</i>	-	-	-	+	-	-	-	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-
<i>Brachionus angularis</i>	-	-	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
<i>B. bidentatus</i>	-	-	-	-	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
<i>B. calyciflorus</i>	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
<i>B. patulus</i>	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>B. quadridentatus</i>	+	-	+	-	-	-	-	+	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-
<i>B. rubens</i>	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cephalodella</i> sp.	+	-	+	-	-	-	-	+	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-
<i>Colurella obtusa</i>	-	+	+	-	-	+	-	-	-	-	+	-	-	-	+	-	+	+	-	-	-	-	-	-
<i>C. uncinata</i>	+	-	+	-	-	-	-	-	-	-	+	-	-	-	-	+	+	-	-	-	+	-	-	-
<i>Conochilus</i> sp.	+	+	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-
<i>Dicranophorus</i> sp.	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Epiphanes</i> sp.	+	+	+	-	-	-	+	-	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-
<i>Euchlanis dilatata</i>	+	+	+	-	+	+	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
<i>Filinia longiseta</i>	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
<i>Keratella</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	+	-	-
<i>K. cochlearis</i>	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>K. tropica</i>	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-
<i>L. aculeate</i>	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. bulla</i>	-	+	+	-	-	-	-	-	+	-	+	-	-	-	+	+	-	+	-	+	-	-	-	-
<i>Lecane closterocerca</i>	-	+	+	-	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
<i>L. crepida</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
<i>L. curvicornis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
<i>L. doryssa</i>	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. hamata</i>	-	+	+	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>L. hornemanni</i>	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. inermis</i>	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. leontina</i>	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. luna</i>	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. lunaris</i>	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-

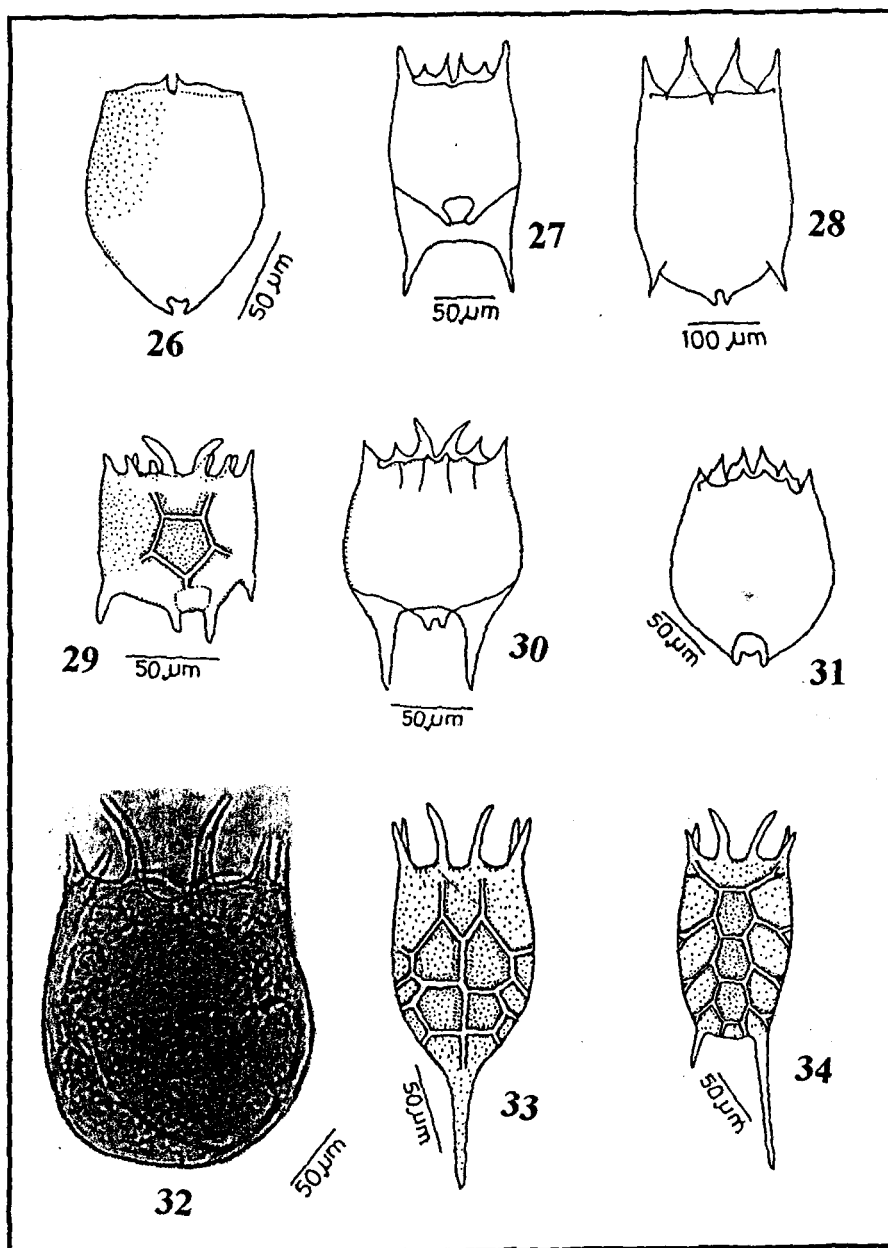
Contd...

Table 15 contd

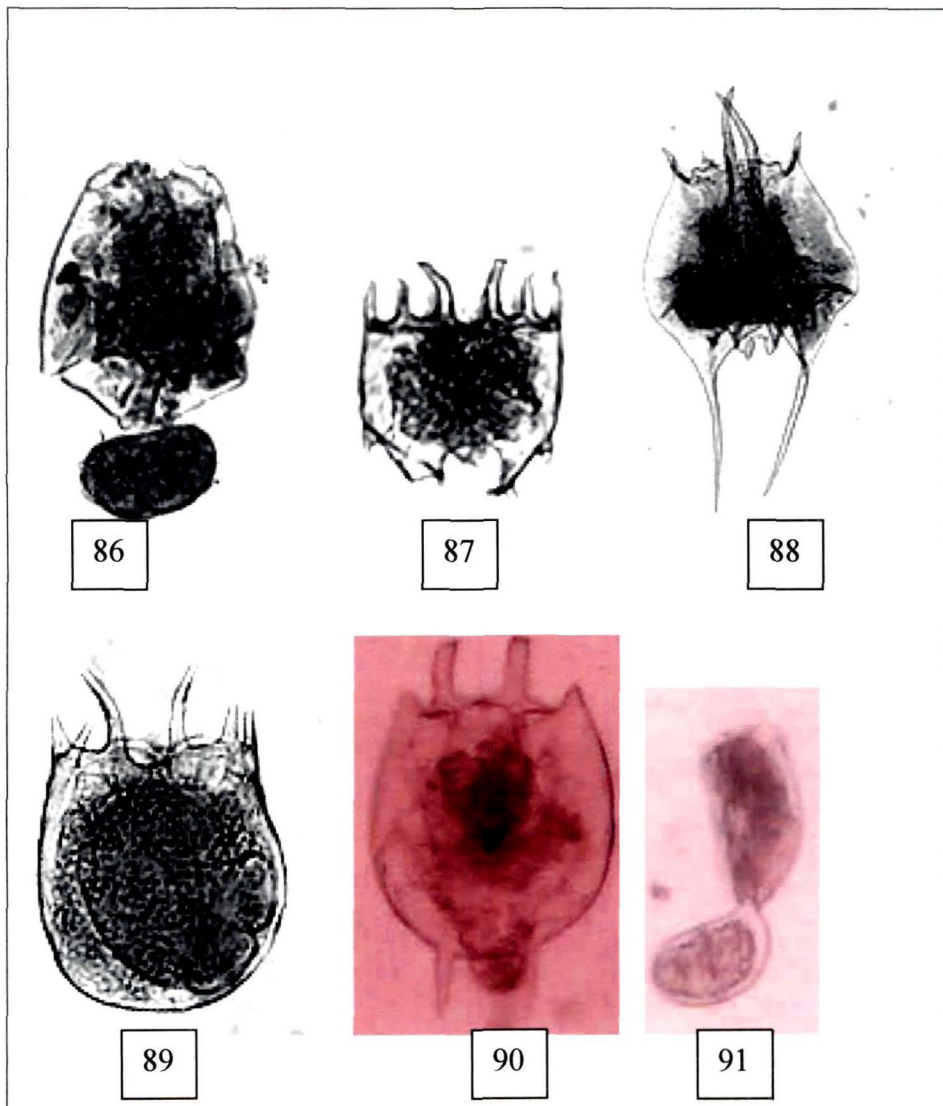
Species↓ Study Sites →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
<i>L. papuana</i>	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. ploenensis</i>	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. pyriformis</i>	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. quadridentata</i>	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. unguitata</i>	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. scutata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>Lepadella ovalis</i>	+	+	+	-	-	-	-	+	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
<i>L. patella</i>	+	+	+	-	-	+	-	+	+	-	-	-	+	-	+	-	-	-	-	-	+	-	-	-
<i>L. acuminata</i>	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Macrochaetus sericus</i>	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
<i>Monommata longiseta</i>	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Mytilina ventralis</i>	+	-	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-
<i>Philodina</i> sp.	+	+	+	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Platyias polyacanthus</i>	+	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>P. quadricornis</i>	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pompholyx</i> sp.	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Polyartha vulgaris</i>	-	-	-	+	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>Rotaria</i> sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scaridium longicaudum</i>	+	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Squatinella mutica</i>	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Synchaeta</i> sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Testudinella patina</i>	+	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>Trichocerca cylindrica</i>	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>T. longiseta</i>	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>T. pusilla</i>	+	+	+	+	+	+	-	+	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-
<i>T. rattus</i>	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-
<i>T. similis</i>	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Trichotria tetractis</i>	-	+	+	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Total (No. of species)	22	22	28	8	7	7	3	15	18	1	23	-	2	6	15	8	4	8	3	3	3	3	1	-

Total No of genera: 28

Total No of species: 60



Brachionus angularis Gosse: Fig. 26, dorsal view; *B. bidentatus* Anderson: Fig. 27, ventral view; *B. calyciflorus* Pallas: Fig. 28, ventral view; *B. patulus* Müller: Fig. 29, dorsal view; *B. quadridentatus* Hermann: Fig. 30, ventral view; *B. rubens* Ehrenberg: Fig. 31, ventral view; *Keratella* sp. Bory St. Vincent: Fig. 32, dorsal view; *Keratella cochlearis* (Gosse): Fig. 33, dorsal view; *K. tropica* (Apstein): Fig. 34, dorsal view.



Brachionus angularis (Gosse): Fig. 86; *B. patulus* Müller: Fig. 87; *B. quadridentatus* Hermann: Fig. 88; *Keratella* sp. Bory de St. Vincent: Fig. 89; *Platyias quadricornis* (Ehrenberg): Fig. 90; *Anuraeopsis fissa* (Gosse): Fig. 91.

Distribution: Bhutan - Trashigang and Samtse districts at Sites 3, 7 and 11

Sub-continent- India (Meghalaya, West Bengal, Orissa, Andhra Pradesh, Gujarat, Tamil Nadu, Kerala, Rajasthan, Punjab and Kashmir)

Elsewhere – Cosmopolitan.

5. *Brachionus quadridentatus* Hermann, 1783 (Fig. 30, 88)

Characters: Lorica rigid and moderately compressed. Anterior margin with six occipital spines; median spines longest and ventrally curved, laterals longer than intermediates. Well developed postero-lateral spines. Ventro-posterior spines prolonged to form a foot-sheath around the foot.

Distribution: Bhutan - Trashiyangtse, Trashigang Mongar, Samdrup Jongkhar and Samtse districts at Sites 1,3, 8,9,11 and 19

Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Bihar, Andhra Pradesh, Madhya Pradesh, Kerala, Rajasthan, Punjab and Jammu and Kashmir)

Elsewhere – Cosmopolitan.

6. *Brachionus rubens* Ehrenberg, 1838 (Fig. 31)

Characters: Lorica oval, dorsoventrally compressed. Anterior margins with short six occipital spines; median and occipital spines with peculiar asymmetrical shape-each spine resulting into a narrow anterior part, then rounding out to form a broad base; median occipitals slightly longer than others; four inner occipital spines with short ridges. Posterior spines absent; foot opening sub-square.

Distribution: Bhutan - Thimphu and Mongar districts at Sites 5 and 8

Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Punjab, Haryana, Rajasthan and Jammu)

Elsewhere – Cosmopolitan.

7. *Keratella* sp. Bory St. Vincent, 1822 (Fig. 32, 89)

Characters: Lorica bulb-shaped; facets not visible. Anterior margins with six occipital spines; two median spines longer and ventrally curved. Posterior spines present or absent; when present, posterior spines are one or two and short and firm. Foot opening typical of brachionids, with almost a rectangular egg attached to foot opening in some observed specimens.

Distribution: Bhutan - Trashigang districts at Sites 17, 20, 21 and 22

Sub-continent-Not known

Elsewhere – Not known.

8. *Keratella cochlearis* (Gosse, 1851) (Fig. 33)

Characters: Lorica elongated-oval and with a median posterior spine of variable length. Dorsal plate with characteristic facets and granulated. Anterior margin with six occipital spines; median longest and ventrally curved, intermediate divergent and shorter than laterals. Single median posterior spine.

Distribution: Bhutan - Samdrup Jongkhar at Site 9

Sub-continent-India (Meghalaya, Assam, West Bengal, Orissa, Kerala, Punjab, Rajasthan, Jammu, Kashmir and Ladak)

Elsewhere – Cosmopolitan.

9. *Keratella tropica* (Apstein, 1907) (Fig. 34)

Characters: Lorica elongate-oval and with six occipital spines; medians occipital longest, pointed and out-curved. Dorsal plate with three median hexagonal plaques and a small squarish area between the last median plaque and the posterior margin of lorica. Posterior spines unequal and variable in length.

Distribution: Bhutan - Trashigang, Lhuntshe and Sarpang districts at Sites 4,14, and 23

Sub-continent- India (Meghalaya, Assam, West Bengal, Bihar, Orissa, Andhra Pradesh, Madhya Pradesh, Kerala, Gujrat, Rajasthan, Punjab, Haryana, Kashmir and Ladak)

Elsewhere – Tropics and sub-tropics.

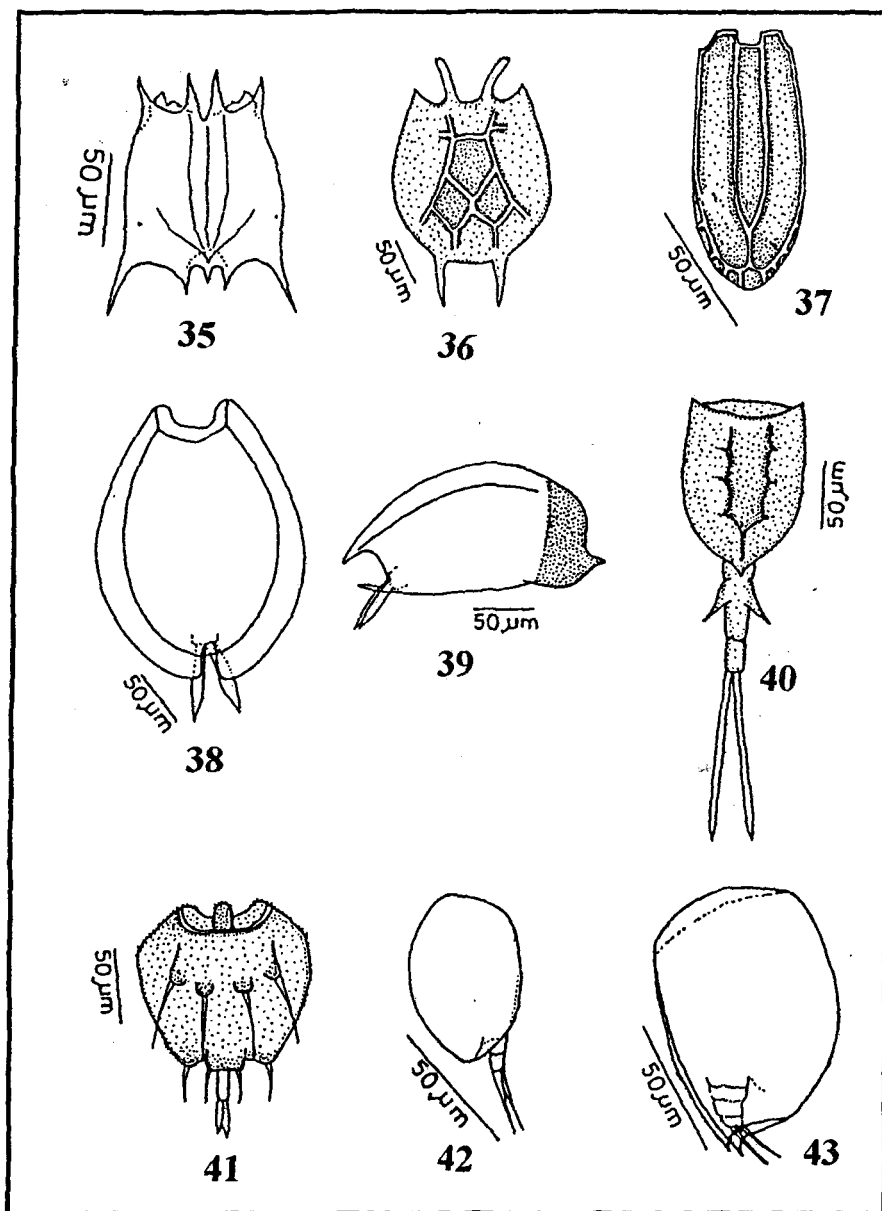
10. *Platyias polyacanthus* (Ehrenberg, 1838) (Fig. 35)

Characters: Lorica compressed dorsoventrally; somewhat rectangular but wider in middle. Anterior surface with six occipital spines; median longest, somewhat straight and form a typical v-shaped sinus; laterals longer than intermediates and curved inwards; intermediates occipital spines peculiarly asymmetrical shaped, each showing a smaller projections rounding towards median posterior spines. Foot opening large and flanked by three median posterior spines. Postero-lateral spines somewhat long and projected away.

Distribution: Bhutan - Trashiyangtse, Samdrup Jongkhar and Bumthang districts at Sites 1,9 and 15

Sub-continent- India, Sri Lanka

Elsewhere – North America



Platyas polyacanthus (Ehrenberg): Fig. 35, dorsal view; *P. quadricornis* (Ehrenberg): Fig. 36, dorsal view; *Amuraeopsis fissa* (Gosse): Fig. 37, dorsal view; *Euchlanis dilatata* Ehrenberg: Fig. 38, dorsal view; *Mytilina ventralis* (Ehrenberg): Fig. 39, lateral view; *Trichotria tetractis* (Ehrenberg): Fig. 40, dorsal view; *Macrochaetus sericus* (Thorpe): Fig. 41, ventral view; *Colurella obtusa* (Gosse): Fig. 42, lateral view; *C. uncinata* (Müller): Fig. 43, lateral view.

11. *Platyias quadricornis* (Ehrenberg, 1838) (Fig. 36, 90)

Characters: Lorica almost circular, tuberculated and pattern of pentagonal facets on dorsal plate. Occipital margins with two stout median spines with rounded tips. Two small posterior spines short and parallel.

Distribution: Bhutan - Trashiyangtse and Trashigang districts at Sites 1 and 3

Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Bihar, Andhra Pradesh, Kerala, Rajasthan, Punjab, Haryana, Kashmir and Ladak)

Elsewhere – Cosmopolitan.

12. *Anuraeopsis fissa* (Gosse, 1951) (Fig. 37, 91)

Characters: Lorica ovate finely stippled, obtusely pointed posteriorly and without markings on the surface; anterior dorsal margin of lorica with a shallow sinus. Ventral plate projecting a little laterally beyond the dorsal plate anteriorly. Foot absent.

Distribution: Bhutan - Trashigang, Mongar and Samtse districts at Sites 2, 8, and 11

Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Bihar, Kerala, Rajasthan, Gujarat, Punjab and Haryana)

Elsewhere – Cosmopolitan.

Family: **Euchlanidae** Bartos, 1959

13. *Euchlanis dilatata* Ehrenberg, 1832 (Fig. 38)

Characters: Lorica oval, flexible, truncate anteriorly and rounded posteriorly. Dorsal plate with a shallow notch at its posterior end. Ventral plate flat, smaller and narrower than dorsal plate. Toes parallel and with pointed tips.

Distribution: Bhutan - Trashiyangtse, Trashigang, Thimphu and Mongar districts at Sites 1, 2, 3, 5, 6, 8, 16, and 18

Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Bihar, Gujarat, Punjab, Jammu, Kashmir and Ladak), Nepal

Elsewhere – Cosmopolitan.

Family: **Mytilinidae** Bartos, 1959

14. *Mytilina ventralis* (Ehrenberg, 1959) (Fig. 39, 92)

Characters: Lorica rigid and laterally compressed; antero-ventral corner with a spine each. Postero-dorsal and postero-ventral spines short and variable. Two moderately long toes.

Distribution: Bhutan - Trashiyangtse, Trashigang, Samdrup Jongkhar and Samtse districts at Sites 1, 6, 9, 11, and 18

Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Bihar, Andhra Pradesh, Gujarat, Madhya Pradesh, Kerala, Punjab, Kashmir and Ladak), Nepal

Elsewhere – Cosmopolitan.

Family: **Trichotridae** Bartos, 1959

15. *Trichotria tetractis* (Ehrenberg, 1830) (Fig. 40, 93)

Characters: Lorica stippled and longer than its width; antero-dorsal corners with small spines. Dorsum with distinct pattern of carinal plates and ridges. Toes long, cylindrical and ending in acute points.

Distribution: Bhutan - Trashiyangtse, Trashigang, Mongar and Bumthang districts at Sites 2, 3, 8, and 15

Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Kerala, Gujrat, Punjab and Kashmir), Nepal

Elsewhere – Cosmopolitan.

16. *Macrochaetus sericus* (Thorpe, 1893) (Fig. 41, 94)

Characters: Lorica horse-shoe shaped and granulated with small spines at its external angles. Dorsum with 8 spines arranged symmetrically along its midline; median caudal spines deeply inserted. Foot two segmented. Toes short and spindle-shaped.

Distribution: Bhutan - Trashiyangtse and Bumthang districts at Sites 1, 2, 15 and 16

Sub-continent- India (Meghalaya, West Bengal, Orissa, Andhra Pradesh and Madhya Pradesh)

Elsewhere – Tropics and sub-tropics.

Family: **Colurellidae** Bartos, 1959

17. *Colurella obtusa* (Gosse, 1886) (Fig. 42)

Characters: Lorica small and laterally compressed; oval with obtuse posterior angles. Foot opening relatively broad. Toes small, slender and pointed.

Distribution: Bhutan - Trashiyangtse, Trashigang, Samtse and Bumthang districts at Sites 2, 3, 6, 11, 15, 17 and 18

Sub-continent- India (Meghalaya, West Bengal and Punjab), Nepal

Elsewhere – Cosmopolitan.

18. *Colurella uncinata* (O.F. Müller, 1773) (Fig. 43, 95)

Characters: Lorica ovate and laterally compressed. Posterior angles of lorica downwardly directed, edges drawn closer. Foot small and stout. Toes two, slender and pointed.

Distribution: Bhutan -Trashiyangtse, Trashigang, Samtse and Bumthang districts at Sites 1, 3, 11, 16, 17 and 21

Sub-continent- India (Meghalaya and West Bengal), Nepal

Elsewhere – Cosmopolitan.

19. *Lepadella (Lepadella) acuminata* (Ehrenberg, 1834) (Fig. 44)

Characters: Lorica almost oval moderately compressed dorsoventrally with anterior dorsal and ventral sinus. Posterior end of lorica produced into a pointed spine of variable length. Foot-groove oval; toes pointed.

Distribution: Bhutan - Trashigang and Samtse districts at Sites 3 and 10

Sub-continent- India (Meghalaya, Assam, Arunachal Pradesh, West Bengal, Orissa, Bihar and Tamil Nadu)

Elsewhere – Cosmopolitan.

20. *Lepadella (Lepadella) ovalis* (Müller, 1786) (Fig. 45)

Characters: Lorica almost circular in outline. Dorsal plate convex and ventral plate nearly flat. Dorsal and ventral sinus with stippled collars. Toes short and pointed.

Distribution: Bhutan - Trashiyangtse, Trashigang, Mongar and Samdrup Jongkhar districts at Sites 1, 2, 3, 8, 9, 15 and 16

Sub-continent- India (Meghalaya, West Bengal, Orissa, Bihar, Kerala, Punjab, Haryana, Ladak, Jammu and Kashmir), Nepal

Elsewhere – Cosmopolitan.

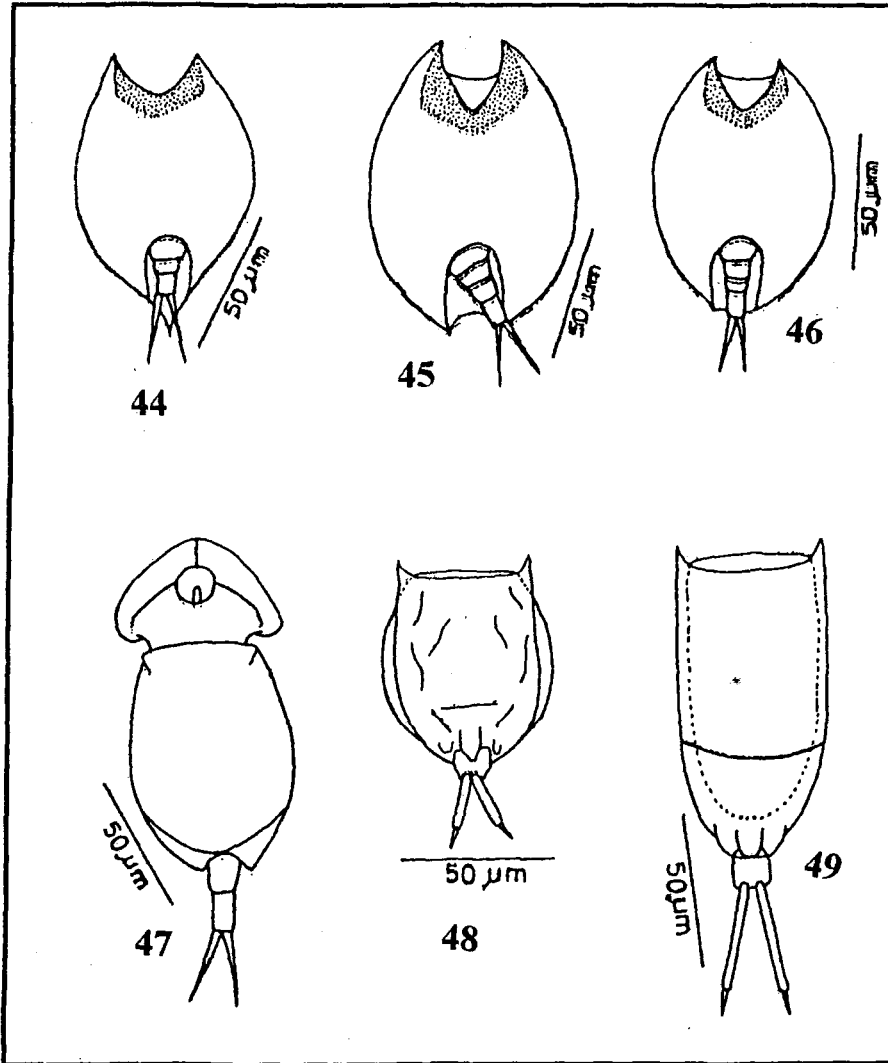
21. *Lepadella (Lepadella) patella* (O.F. Müller, 1773) (Fig. 46)

Characters: Lorica oval and dorsal plate strongly arched; anterior dorsal and ventral sinus with stippled collars. Foot-groove parallel-sided to semicircular and its edges projecting at the posterior end. Toes pointed.

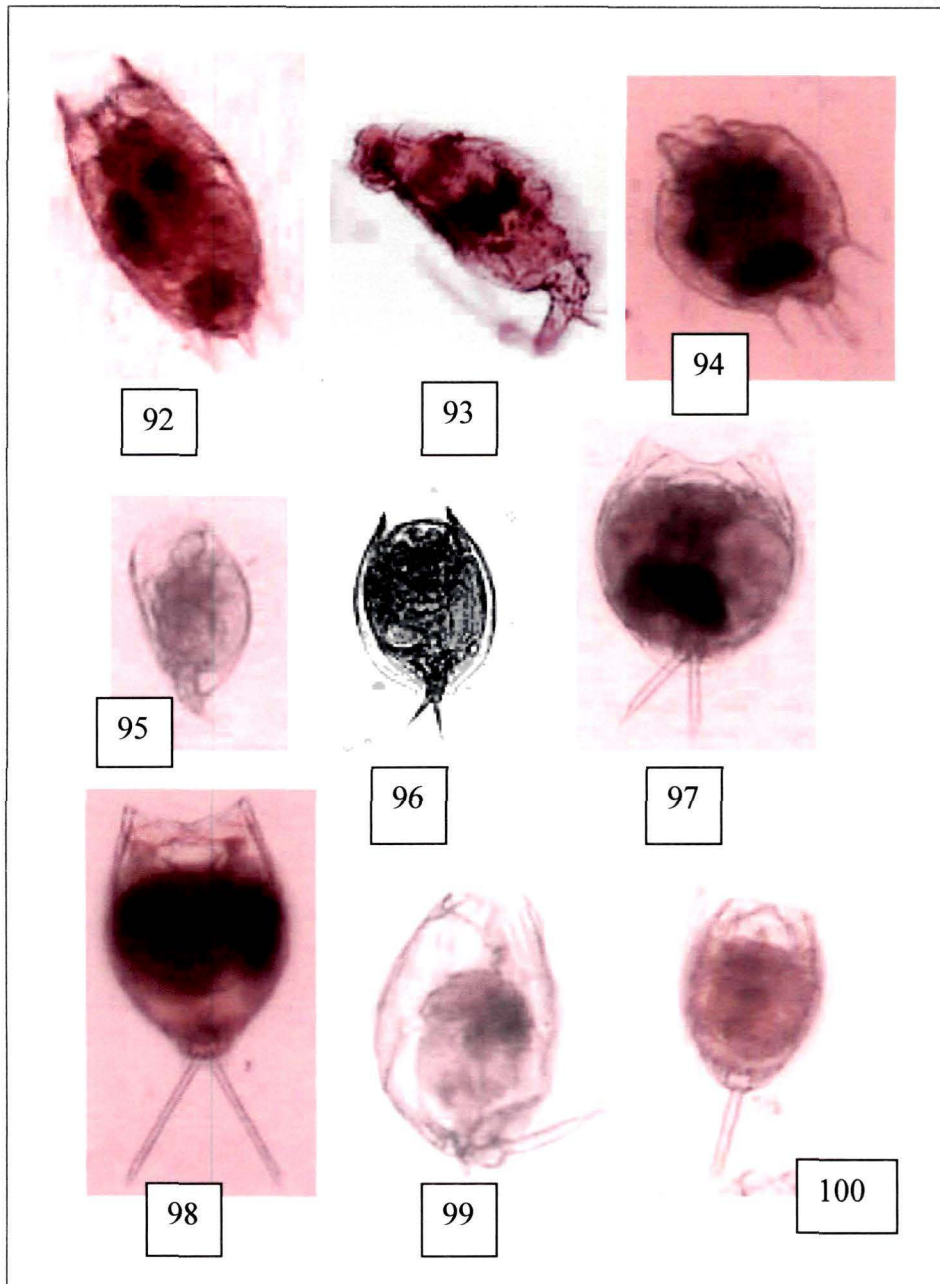
Distribution: Bhutan - Trashiyangtse, Trashigang, Mongar, Paro and Samdrup Jongkhar districts at Sites 1, 2, 3, 6, 8, 9, 13, 15 and 21

Sub-continent- India (all North-Eastern States, West Bengal, Orissa, Bihar, Rajasthan, Gujarat, Punjab, Ladak and Kashmir), Nepal

Elsewhere – Cosmopolitan.



Lepadella (Lepadella) acuminata (Ehrenberg): Fig. 44, ventral view; *L. (L.) ovalis* (Müller): Fig. 45, ventral view; *L. (L.) patella* (Müller): Fig. 46, ventral view; *Squatinella mutica* (Ehrenberg): Fig. 47, dorsal view; *Lecane (Lecane) aculeata* (Jakubski): Fig. 48, ventral view; *L. (L.) crepida* Haring: Fig. 49, ventral view.



Mytilina ventralis (Ehrenberg): Fig. 92; *Trichotria tetractis* (Ehrenberg): Fig. 93; *Macrochaetus sericus* (Thorpe): Fig. 94; *Colurella uncinata* (Müller): Fig. 95; *Lepadella patella* (Müller): Fig. 96; *Lecane curvicornis* (Murray): Fig. 97; *L. leontina* (Turner): Fig. 98. *Lecane bulla* (Gosse): Fig. 99; *L. lunaris* (Ehrenberg): Fig. 100.

22. *Squatinella mutica* (Ehrenberg, 1832) (Fig. 47)

Characters: Body oblong-ovate and transparent. Trunk with oblong-ovate lorica; Posterior end of trunk lorica with a notch. First foot segment covered by a projection of dorsal plate. Toes long, slender and acutely pointed.

Distribution: Bhutan - Samtse district at Site 11

Sub-continent- India (Meghalaya, West Bengal and Ladak)

Elsewhere – Cosmopolitan.

Family: **Lecanidae** Bartos, 1959

23. *Lecane (Lecane) aculeata* (Jakubski, 1912) (Fig. 48)

Characters: Lorica elongate and oval with straight and coincident anterior margins. Dorsal plate with markings. Ventral plate narrower than dorsal plate and with large spines curving out at its external edge. Posterior segment broader and semi-circular. Toes parallel sided and end into slender claws.

Distribution: Bhutan - Trashiyangtse and Trashigang districts at Sites 1, 2 and 3

Sub-continent- India (Meghalaya, West Bengal and Orissa)

Elsewhere – Tropics and sub-tropics.

24. *Lecane (Lecane) crepida* Haring, 1914 (Fig. 49)

Characters: Lorica elongated, parallel-sided and with anterior margins almost straight. External angles of ventral plate with anteriorly directed spines. Dorsal plate smaller than ventral plate. Second foot joint broadly square and projecting beyond lorica. Toes parallel sided and each with a pointed claw.

Distribution: Bhutan - Trashigang district at Sites 18 and 19

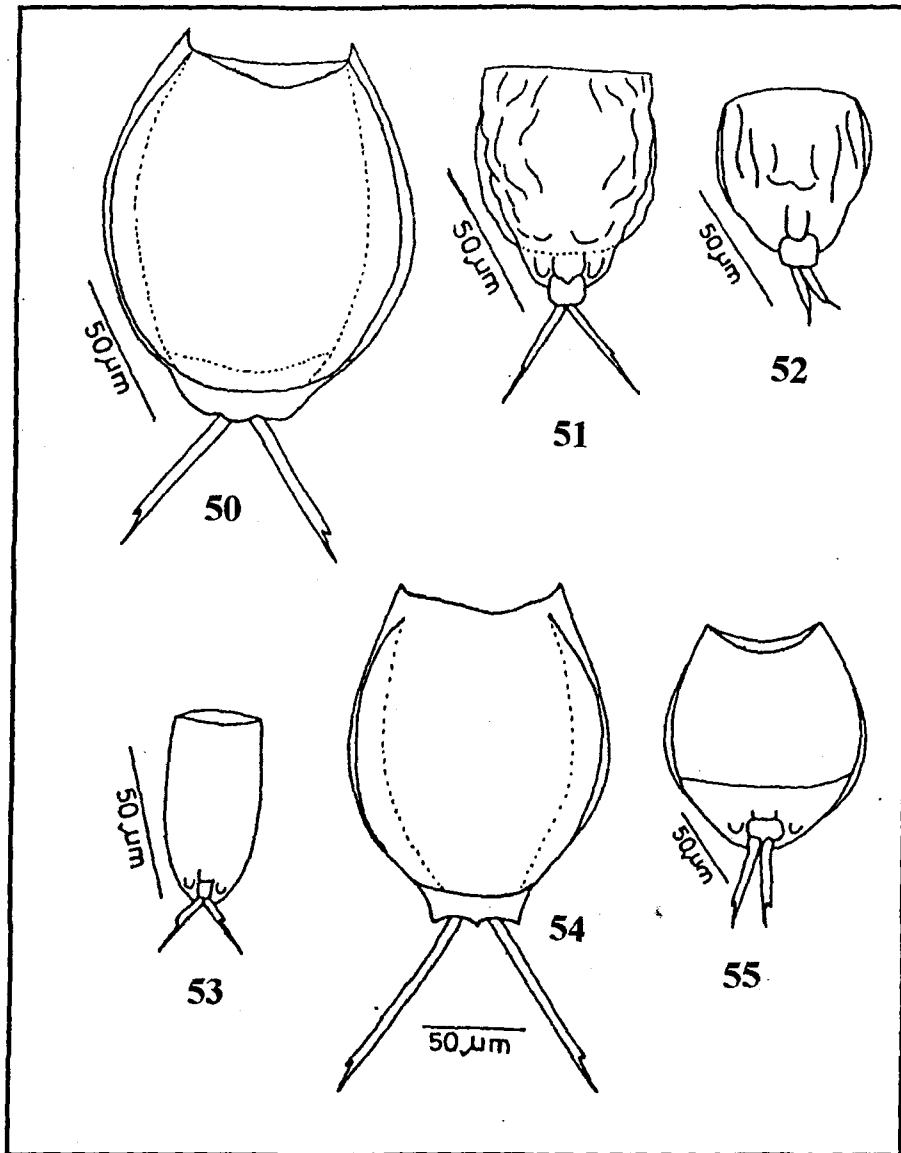
Sub-continent- India (Meghalaya, Assam, West Bengal, Tamil Nadu, Gujarat and Punjab),
Nepal

Elsewhere – Tropics and sub-tropics.

25. *Lecane (Lecane) curvicornis* (Murray, 1913) (Fig. 50, 97)

Characters: Lorica pyriform, anterior margins coincident with a broad v-shaped sinus; external edges with prominent spines. Dorsal plate narrower than ventral plate and without any surface markings. Posterior segment of ventral plate with transverse fold. Toes long and straight. Claws small with a basal spicule.

Distribution: Bhutan - Trashigang district at Site 18



Lecane (Lecane) curvicornis (Murray): Fig. 50, ventral view; *L. (L.) doryssa* Haring: Fig. 51, ventral view; *L. (L.) hornemanni* (Ehrenberg): Fig. 52, ventral view; *L. (L.) inermis* (Bryce): Fig. 53, ventral view; *L. (L.) leontina* (Turner): Fig. 54, dorsal view; *L. (L.) luna* (Müller): Fig. 55, ventral view.

Sub-continent- India (Meghalaya, West Bengal, Bihar, Andhra Pradesh and Madhya Pradesh)

Elsewhere – Tropics and sub-tropics.

26. *Lecane (Lecane) doryssa* Haring, 1914 (Fig. 51)

Characters: Lorica almost oval, flexible and with surface markings. Anterior margins almost straight with external angles. Posterior segment semi-circular. Toes short and terminating into pointed and undifferentiated claws.

Distribution: Bhutan - Trashiyangtse district at Site 2

Sub-continent- India (only Meghalaya)

Elsewhere – Eastern Asia, Indonesia and central Europe.

27. *Lecane (Lecane) hornemanni* (Ehrenberg, 1834) (Fig. 52)

Characters: Lorica broadly ovate, slightly convex and without any spines at external angles. Dorsal plate semi-circular and broader than ventral plate. Toes stout, tapering gradually and with slightly curved points.

Distribution: Bhutan - Trashiyangtse district at Site 1

Sub-continent- India (Meghalaya, West Bengal, Andhra Pradesh, Tamil Nadu, Gujarat and Kashmir)

Elsewhere – Tropics and sub-tropics.

28. *Lecane (Lecane) inermis* (Bryce, 1892) (Fig. 53)

Characters: Lorica elongated and flexible. Anterior margins almost straight and without spines at anterior external angles. Toes small and terminating into long and pointed claws.

Distribution: Bhutan - Trashiyangtse, Samdrup Jongkhar district at Site 1 and 9

Sub-continent- India (Meghalaya and West Bengal), Nepal

Elsewhere – Cosmopolitan.

29. *Lecane (Lecane) leontina* (Turner, 1892) (Fig. 54, 98)

Characters: Lorica oblong-ovate; anterior dorsal and ventral sinus broadly v-shaped. Ventral plate broader and with triangular spines at anterior external angles. Posterior segment projecting over foot. Toes long, parallel-sided and terminating into claws; each claw with a basal spicule.

Distribution: Bhutan - Samtse district at Site 11

Sub-continent- India (all North-Eastern States, West Bengal, Orissa, Bihar, Andhra Pradesh, Madhya Pradesh and Punjab)

Elsewhere – Tropics and sub-tropics.

30. *Lecane (Lecane) luna* (Müller, 1773) (Fig. 55)

Characters: Lorica ovate to sub-circular in outline. Dorsal plate broader than ventral plate. Anterior ventral sinus v-shaped with cusp-shaped external angles. Toes stout, parallel sided and slightly swollen at their bases; claws with basal spicule.

Distribution: Bhutan - Trashigang and Trashigang district at Site 1, 2 and 3

Sub-continent- India (all North-Eastern States, West Bengal, Orissa, Bihar, Gujarat, Rajasthan, Punjab Kashmir, Jammu and Ladak), Nepal

Elsewhere – Cosmopolitan.

31. *Lecane (Lecane) papuana* (Murray, 1913) (Fig. 56)

Characters: Lorica oval to circular; anterior dorsal margin straight, anterior ventral margin undulating with a shallow median sinus. Ventral plate slightly narrower than dorsal plate. Posterior segment small and rounded. Toes moderately long, parallel-sided and terminating into claws.

Distribution: Bhutan - Trashigang and Mongar district at Sites 3 and 8

Sub-continent- India (Meghalaya, Nagaland, Manipur, Assam, West Bengal, Orissa, Bihar, Tamil Nadu, Kashmir and Ladak)

Elsewhere – Tropics and sub-tropics.

32. *Lecane (Lecane) signifera ploenensis* (Voigt, 1902) (Fig. 57)

Characters: Lorica elongate-oval; spines at anterior external angles relatively longer. Dorsal plate truncate posteriorly and with distinct surface markings. Toes relatively elongated and terminating into acute points.

Distribution: Bhutan - Samtse district at Site 11

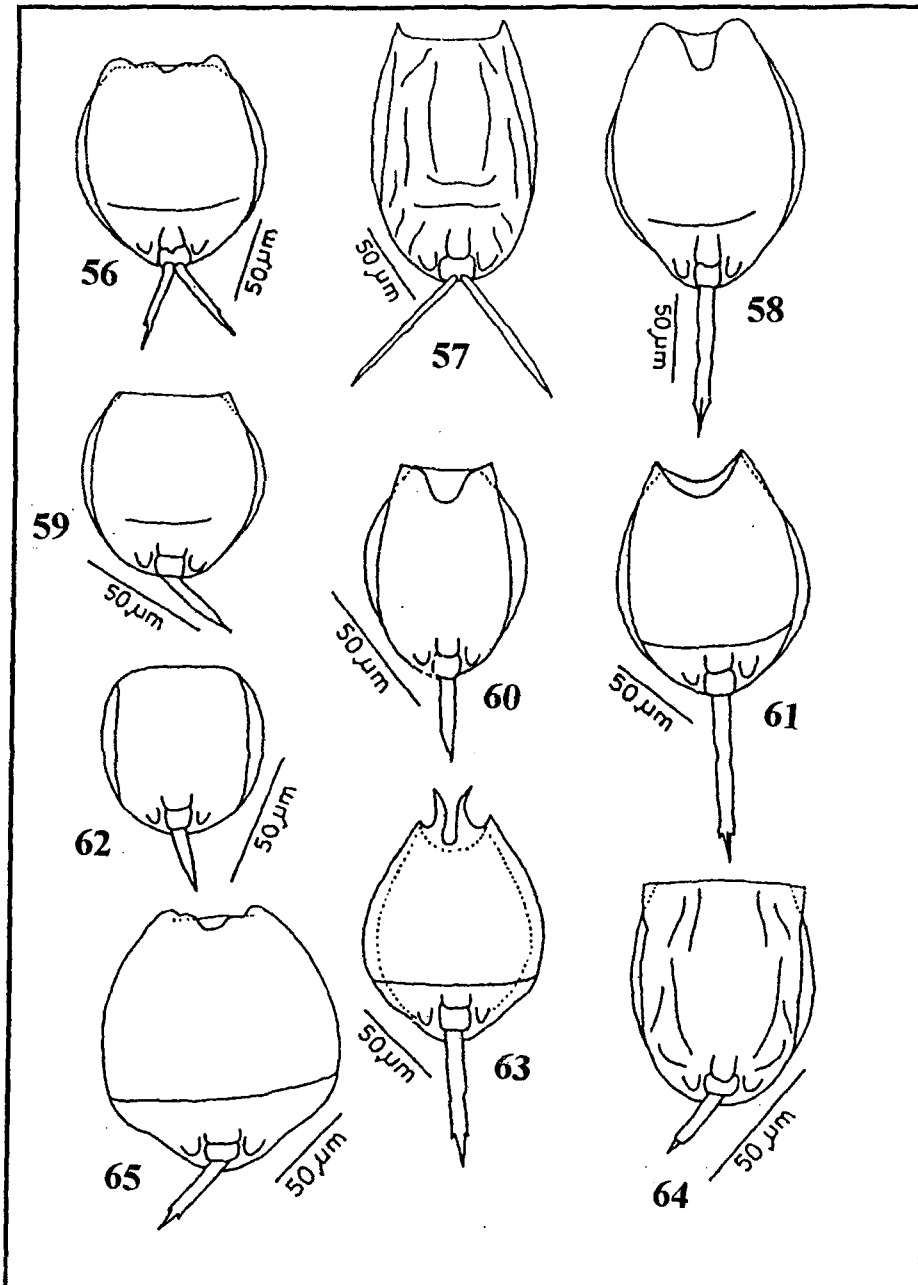
Sub-continent- India (Meghalaya, Mizoram, West Bengal, Gujarat and Punjab)

Elsewhere – Cosmopolitan.

33. *Lecane (Monostyla) bulla* (Gosse, 1851) (Fig. 58, 99)

Characters: Lorica oblong-ovate; anterior dorsal margin with a shallow sinus, anterior ventral margin with deep sinus. Ventral plate equally broad or slightly narrower than dorsal plate. Toes long and terminating into a long and pointed claw; claw with a distinct median line but undivided.

Distribution: Bhutan - Trashiyangtse, Trashigang, Samdrup Jongkhar, Samtse and Bumthang districts at Sites 2, 3, 9, 11, 15, 16, 18 and 20



Lecane (Lecane) papuana (Murray): Fig. 56, ventral view; *L. (L.) signifera ploenensis* (Voigt): Fig. 57, ventral view; *L. (Monostyla) bulla* (Gosse): Fig. 58, ventral view; *L. (M.) closterocerca* (Schmarda): Fig. 59, ventral view; *L. (M.) hamata* (Stokes): Fig. 60, dorsal view; *L. (M.) lunaris* (Ehrenberg): Fig. 61, ventral view; *L. (M.) pyriformis* (Daday): Fig. 62, ventral view; *L. (M.) quadridentata* (Ehrenberg): Fig. 63, ventral view; *L. (M.) scutata* (Harring and Myers): Fig. 64, ventral view; *L. (M.) unguitata* (Fadeev): Fig. 65, ventral view.

Sub-continent- India (all North-Eastern States, West Bengal, Orissa, Bihar, Andhra Pradesh, Tamil Nadu, Rajasthan, Gujarat, Punjab, Jammu and Kashmir), Nepal

Elsewhere – Cosmopolitan.

34. *Lecane (Monostyla) closterocerca* (Schmarda, 1859) (Fig. 59)

Characters: Lorica broadly oval with concave anterior margins; anterior external angles rounded. Ventral plate narrower than dorsal plate. Toes parallel sided up to half of its length then tapering to a slender point.

Distribution: Bhutan - Trashiyangtse, Trashigang and Bumthang districts at Sites 2, 3, 6, 15 and 16

Sub-continent- India (all North-Eastern states, Orissa, Tamil Nadu, Gujarat, Rajasthan, Punjab, Kashmir, Ladak), Nepal

Elsewhere – Cosmopolitan.

35. *Lecane (Monostyla) hamata* (Stokes, 1896) (Fig. 60)

Characters: Lorica elongate-oval. Anterior dorsal margin with a shallow sinus and ventral margin with deep v-shaped sinus. Toe parallel sided up to about half and tapering to an acute point.

Distribution: Bhutan - Trashiyangtse, Trashigang, Mongar and Bumthang districts at Sites 2, 3, 8 and 15

Sub-continent- India (Meghalaya, Mizoram, Assam, West Bengal, Orissa, Tamil Nadu, Gujarat, Rajasthan, Punjab and Kashmir), Nepal

Elsewhere – Cosmopolitan.

36. *Lecane (Monostyla) lunaris* (Ehrenberg, 1832) (Fig. 61, 100)

Characters: Lorica broadly ovate; anterior margin with a shallow lunate sinus. Dorsal plate semi-circular to pear-shaped and ventral plate broadly oval and narrower than dorsal plate. Toe long and parallel sided; claw with a median furrow and two basal spicules.

Distribution: Bhutan - Trashiyangtse, Trashigang, Samdrup Jongkhar, and Bumthang districts at Sites 1, 2, 3, 4, 9, 15, and 20

Sub-continent- India (all North-Eastern states, West Bengal, Orissa, Bihar, Gujarat and Kashmir), Nepal

Elsewhere – Cosmopolitan.

37. *Lecane (Monostyla) pyriformis* (Daday, 1905) (Fig. 62)

Characters: Lorica pyriform, anterior margins straight or slightly convex with rounded external angles. Ventral plate narrower than dorsal plate. Second foot-joint sub-square. Toe parallel sided almost up to half and then tapering to a slender tip.

Distribution: Bhutan - Samtse district at Site 11

Sub-continent- India (Meghalaya, West Bengal, Orissa, Bihar and Punjab)

Elsewhere – Cosmopolitan.

38. *Lecane (Monostyla) quadridentata* (Ehrenberg, 1832) (Fig. 63)

Characters: Lorica broadly ovate to pyriform. Anterior dorsal margin with two out-curved spines; ventral margin with v-shaped sinus and its external angles produced into minute frontal spines. Toe long and parallel sided; claw pointed with two basal spicules.

Distribution: Bhutan - Trashigang and Samtse districts at Sites 3 and 7

Sub-continent- India (Meghalaya, Manipur, Mizoram, Nagaland, Assam, Orissa, Bihar, Andhra Pradesh, Madhya Pradesh, Rajasthan, Punjab, Haryana and Kashmir), Nepal

Elsewhere – Cosmopolitan.

39. *Lecane (Monostyla) scutata* (Harring and Myers, 1926) (Fig. 64)

Characters: Lorica oval; anterior margin coincident and slightly concave; anterior ventral margin broader and produced into sharp corners at external angles. Ventral plate narrower than dorsal plate and almost parallel-sided. Toes parallel sided; claw short and pointed.

Distribution: Bhutan - Bumthang district at Site 15

Sub-continent- India (Meghalaya and west Bengal)

Elsewhere – Cosmopolitan.

40. *Lecane (Monostyla) unguitata* (Fadeev, 1925) (Fig. 65)

Characters: Lorica broadly circular with relatively small anterior opening. Anterior dorsal margin straight and anterior ventral margin undulating with deep median sinus and rounded external angles. Dorsal plate pyriform, truncate posteriorly and smaller than ventral plate. Claw pointed with indistinct furrow and with two basal spicules.

Distribution: Bhutan - Samtse district at Site 11

Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Bihar and Gujarat)

Elsewhere – Paleotropical.

Family: Notommatidae Remane, 1933

41. *Cephalodella* sp. Bory de St. Vincent, 1826 (Fig. 66, 101)

Characters: Body elongated and slightly curved; body short and stout with thin dorsal and ventral plate. Foot ventrally directed; toes slightly bent and pointed.

Distribution: Bhutan - Trashiyangtse, Trashigang, Mongar, Samdrup Jongkhar, and Bumthang districts at Sites 1, 3, 8, 9, 15, and 18

Sub-continent- India (Meghalaya, West Bengal, Andhra Pradesh, Gujarat, Kashmir and Ladak), Nepal

Elsewhere – Cosmopolitan.

42. *Scaridium longicaudum* (Müller, 1786) (Fig. 67, 102)

Characters: Lorica thin and somewhat cylindrical. Foot three segmented, distal segment longest; foot segment with striated muscles. Toes long, almost parallel-sided and with blunt tips.

Distribution: Bhutan - Trashiyangtse, Trashigang and Samdrup Jongkhar districts at Sites 1, 3 and 9

Sub-continent - India (Meghalaya, Mizoram, Nagaland, Assam, west Bengal, Orissa, Bihar, Gujarat and Punjab), Nepal

Elsewhere – Cosmopolitan.

43. *Monommata longiseta* (Müller, 1786) (Fig. 68, 103)

Characters: Lorica thin transparent and almost cylindrical. Foot distinctly segmented; Toes long and unequal.

Distribution: Bhutan - Trashiyangtse and Samtse districts at Sites 1, 2 and 11 Sub-continent- India (Meghalaya and West Bengal)

Elsewhere – Cosmopolitan.

Family: Trichocercidae Remane, 1933

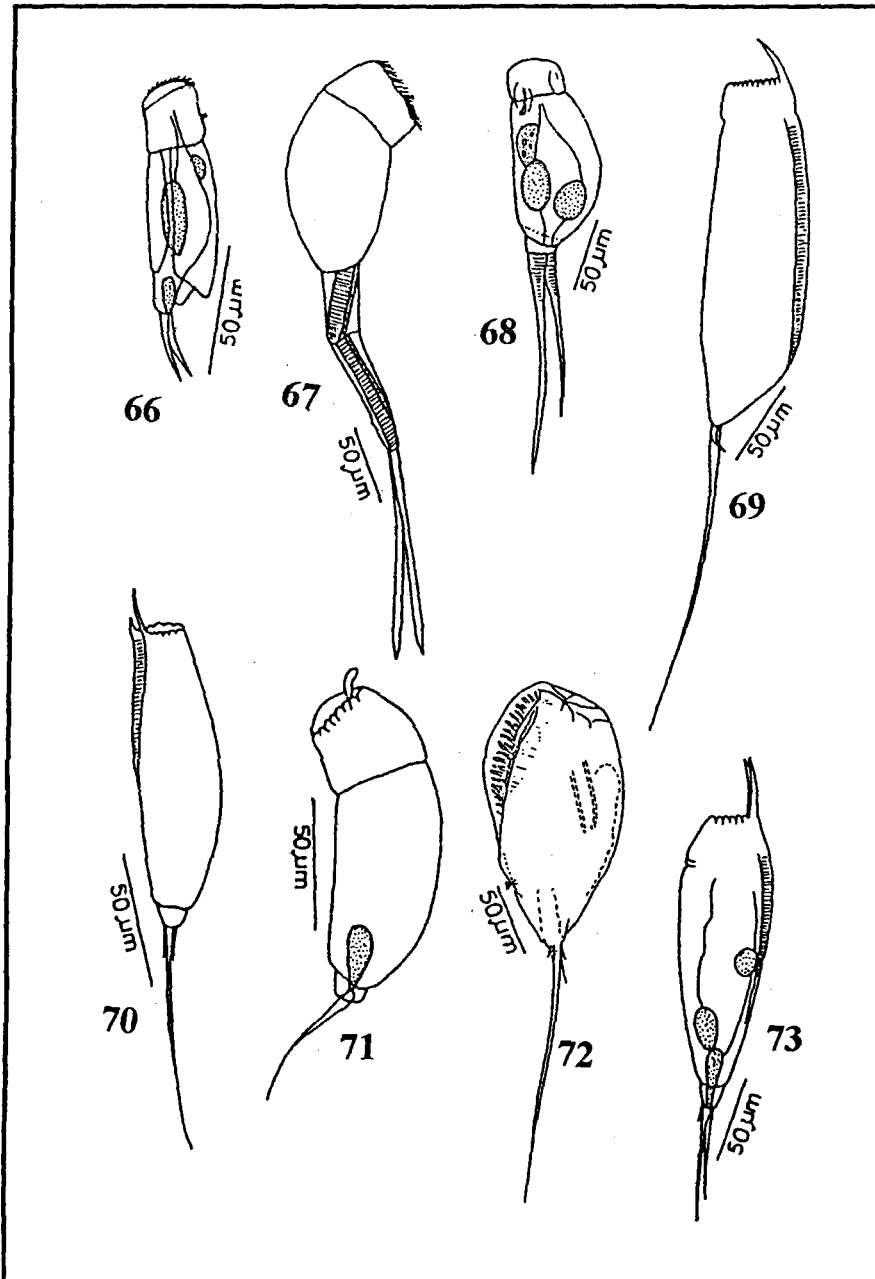
44. *Trichocerca (Trichocerca) cylindrica* (Inshof, 1891) (Fig. 69)

Characters: Body long and cylindrical. Anterior end with a median dorsal spine and a number of longitudinal folds. Lorica thin, with a striated area. Left toe almost as long as lorica; right toe reduced to a scaly spine. Lateral antennae located in the middle of the dorsal crest.

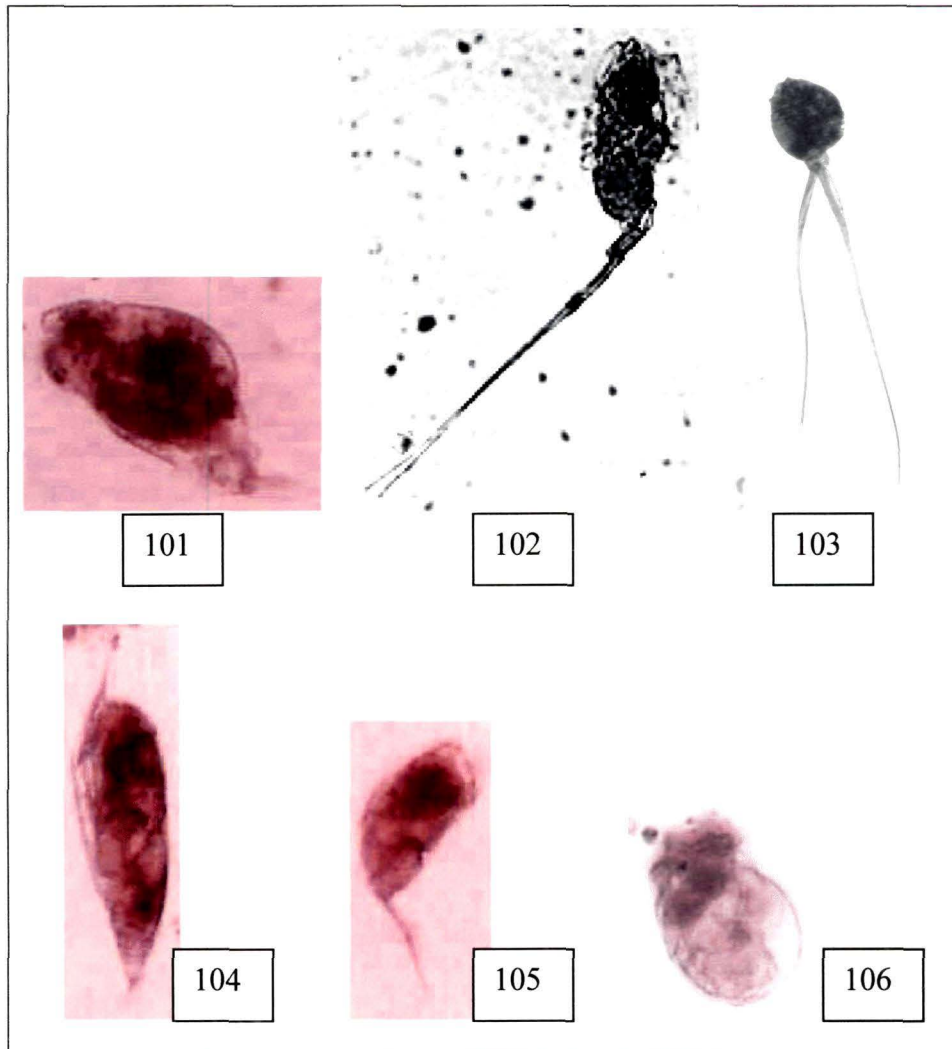
Distribution: Bhutan - Trashiyangtse and Trashigang districts at Sites 2 and 3

Sub-continent- India (Meghalaya, West Bengal, Orissa and Kashmir), Nepal

Elsewhere – Palaearctic and Nearctic regions and Sri Lanka.



Cephalodella sp. Bory de St. Vincent: Fig. 66, lateral view; *Scaridium longicaudum* (Müller): Fig. 67, lateral view; *Monommata longiseta* (Müller): Fig. 68, lateral view; *Trichocerca (Trichocerca) cylindrica* (Imhof): Fig. 69, lateral view; *T. (T.) longiseta* (Schrank): Fig. 70, lateral view; *T. (T.) pusilla* (Lauterborn): Fig. 71, lateral view; *T. (T.) rattus* (Ehrenberg): Fig. 72, ventral view; *T. (T.) similis* ((Wierzejski): Fig. 73, lateral view.



Cephalodella sp. Bory de St. Vincent: Fig. 101; *Scaridium longicaudum* (Müller): Fig. 102; *Monommata longiseta* (Müller): Fig. 103; *Trichocerca similis* (Wierzejski): Fig. 104; *T. pusilla* (Lauterborn): Fig. 105; *Ascomorpha* sp. Perty: Fig. 106.

45. *Trichocerca (Trichocerca) longiseta* (Schrank, 1802) (Fig. 70)

Characters: Lorica long and slender; anterior margin with a long spine, a shorter spine and two small projections. Striated area up to middle of trunk. Left toe equal to about half of the body length or more and right toe small; substyli present.

Distribution: Bhutan - Trashiyangtse and Trashigang districts at Sites 2 and 3

Sub-continent- India (Meghalaya, Jammu, Kashmir and Ladak)

Elsewhere – Palaearctic and Nearctic regions.

46. *Trichocerca (Trichocerca) pusilla* (Lauterborn, 1898) (Fig. 71, 105)

Characters: Body short, slender and cylindrical; a distinct head without any crest for striated area. Anterior end straight. Toes unequal; left toe moderately long and ventrally directed; right toe very small.

Distribution: Bhutan - Trashiyangtse, Trashigang, Mongar, Samdrup Jongkhar, Bumthang, Thimphu, Samtse and Sarpang districts at Sites 1, 2, 3, 4, 5, 6, 8, 9, 11, 14 and 15

Sub-continent- India (Meghalaya, West Bengal, Orissa and Bihar), Nepal

Elsewhere – Cosmopolitan.

47. *Trichocerca (Trichocerca) rattus* (Ehrenberg, 1830) (Fig. 72)

Characters: Body broadly oval, plumpy and head indistinct. Left toe long and right toe reduced with few stylets present at the base of the foot.

Distribution: Bhutan - Trashigang and Samtse districts at Sites 3, 11 and 17

Sub-continent- India and Nepal

Elsewhere – Cosmopolitan.

48. *Trichocerca (Trichocerca) similis* (Wierzejski, 1893) (Fig. 73, 104)

Characters: Body long, slender and tapering posteriorly. Anterior end with two long spines dorsally separated by a small hump. Dorsal keel extending from base of anterior spines up to one-third of body length. Foot two segmented. Toes short and unequal.

Distribution: Bhutan - Samtse district at Site 11

Sub-continent- India (Meghalaya, West Bengal, Orissa, Bihar and Gujarat), Nepal

Elsewhere – Cosmopolitan

Family: Asplanchnidae Haring & Myers, 1926

49. *Asplanchna priodonta* Gosse, 1850 (Fig. 74)

Characters: Body illoricate, transparent and sacciform. Contractile vesicle small and rounded. Gastric glands rounded. Vitellarium rounded. Rami serrate on inner side, broad at free ends. Foot absent.

Distribution: Bhutan - Trashigang, Samtse, Sarpang and Trashiyangtse districts at Sites 4, 11, 14 and 16

Sub-continent- India (Meghalaya, West Bengal, Bihar, Gujarat, Jammu and Kashmir)

Elsewhere – Cosmopolitan

Family: **Synchaetidae** Remane, 1933

50. *Synchaeta* sp. Ehrenberg, 1832 (Fig. 75)

Characters: Body illoricate, conical and fusiform. Foot short and unsegmented; toes two, short and pointed.

Distribution: Bhutan - Mongar district at Site 8

Sub-continent- India (Meghalaya, Tamil Nadu and Kashmir)

Elsewhere – Cosmopolitan

51. *Polyarthra vulgaris* Carlin, 1943 (Fig. 76)

Characters: Body broadly cylindrical, with ventral appendages. Apical field with two ciliated antennae, lateral antennae located in the posterior third part of the body. Serrate paddles feather-shaped and slightly longer than the body; each blade with a distinct mid-rib and lateral ribs.

Distribution: Bhutan - Trashigang, Mongar, Samtse and Bumthang districts at Sites 4, 8, 11 and 15

Sub-continent-India (Meghalaya, Assam, West Bengal, Orissa, Bihar, Punjab and Kashmir)

Elsewhere – Cosmopolitan

Family: **Dicranophoridae** Remane, 1933

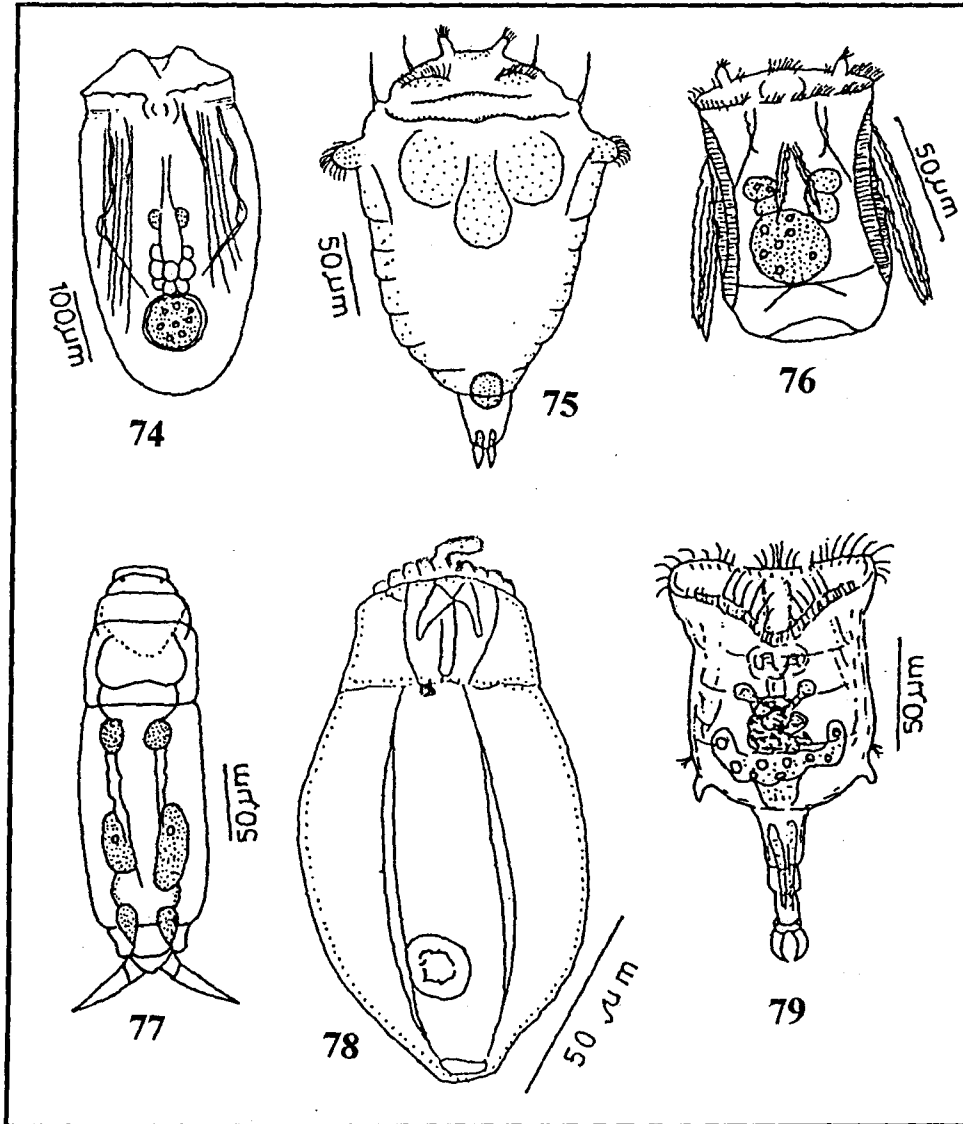
52. *Dicranophorus* sp. Nitzsch, 1827 (Fig. 77)

Characters: Body slender and spindle-shaped; with longitudinal folds. Foot small; toes long and ventrally directed.

Distribution: Bhutan - Trashiyangtse district at Site 2

Sub-continent- India (Meghalaya and West Bengal)

Elsewhere – Cosmopolitan



Asplanchna priodonta Gosse: **Fig. 74**, dorsal view; *Synchaeta* sp. Ehrenberg: **Fig. 75**, dorsal view; *Polyarthra vulgaris* Carlin: **Fig. 76**, ventral view; *Dicranophorus* sp. Nitzsch: **Fig. 77**, dorsal view; *Ascomorpha* sp. Perty: **Fig. 78**, *Epiphanes* sp. Ehrenberg: **Fig. 79**, dorsal view.

Family: Gastropodidae Remane, 1933

53. *Ascomorpha* sp. Perty, 1850 (Fig. 78)

Characters: Body oval; thin lorica; corona with apical ring of cilia; apical tied with stiff tentacle and tufts of cilia. Stomach large, bilobed, intestine obliterated.

Distribution: Bhutan - Mongar, Samdrup Jongkhar and Samtse districts at Site 8, 9 and 11
Sub-continent- India (Meghalaya, West Bengal, Jammu and Ladak)

Elsewhere – Cosmopolitan

Family: Epiphanidae Ehrenberg, 1832

54. *Epiphanes* sp. Ehrenberg, 1832 (Fig. 79)

Characters: Body sacciform; corona with apical ring of cilia. Two postero-lateral spines present, short, firm and slightly curved inwards. Foot long and three segmented; toes short and curved inwards.

Distribution: Bhutan - Trashiyangtse, Trashigang, Samtse and Bumthang districts at Site 1, 2, 3, 7, 11, 15 and 16

Sub-continent- India (Kashmir)

Elsewhere – Cosmopolitan

Order: Gnesiotrocha De Beauchamp, 1965

Family: Conochilidae Bartos, 1959

55. *Conochilus* sp. Ehrenberg, 1834 (Fig. 80)

Characters: Body transparent, vase-shaped with long, contractile and unsegmented foot. Colonial and with gelatinous case. Digestive system U-shaped, anus situated dorsally.

Distribution: Bhutan - Trashiyangtse, Samtse and Sarpang districts at Site 1, 2, 11 and 14
Sub-continent- India (Meghalaya, West Bengal and Jammu)

Elsewhere – Cosmopolitan

Family: Testudinellidae Bartos, 1959

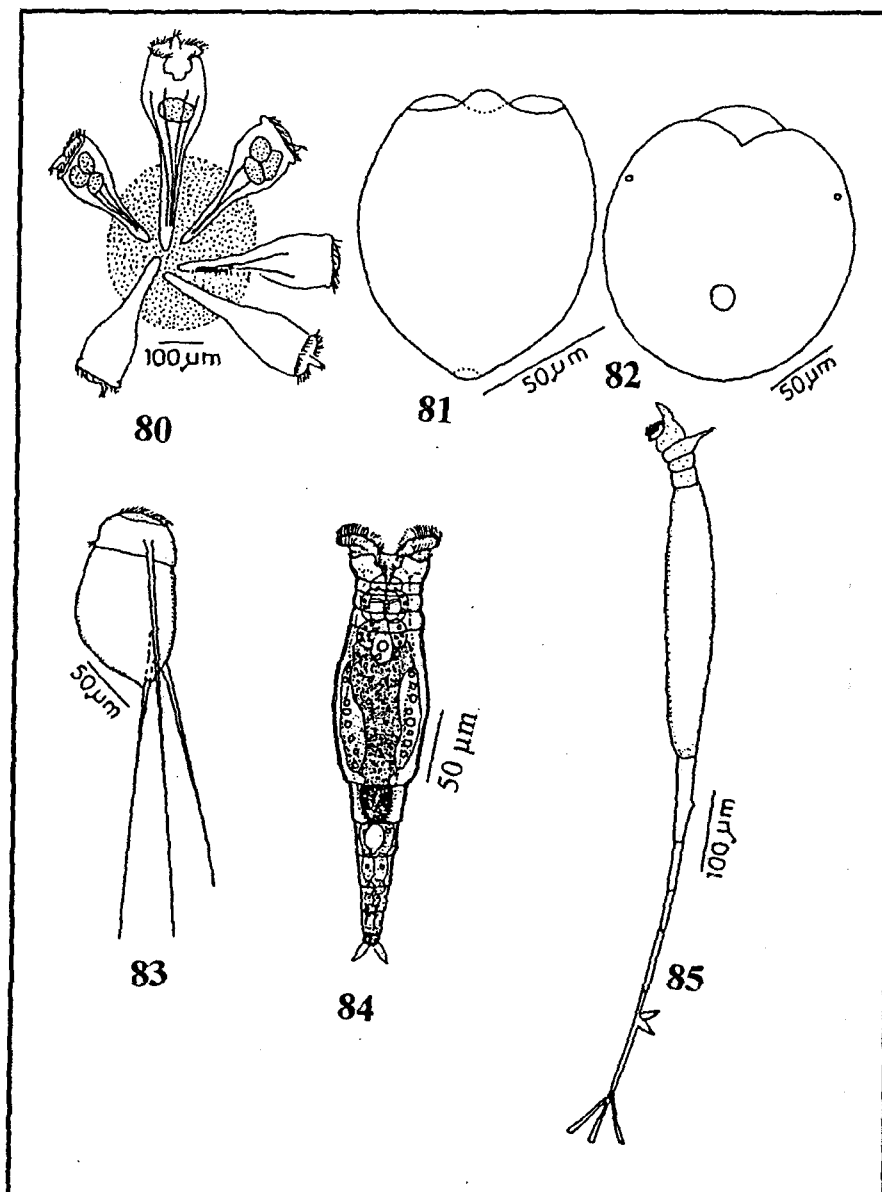
56. *Pompholyx* sp. Gosse, 1851 (Fig. 81)

Characters: Body with thin lorica, oval. Without foot. Corona with simple circumapical band of cilia. Cloacal aperture terminal.

Distribution: Bhutan - Trashiyangtse, Trashigang, Samtse and Bumthang districts at Site 1, 2, 3, 7, 11, 15 and 16

Sub-continent- India (Meghalaya, Assam, Orissa, Punjab, Kashmir and Ladak)

Elsewhere – Cosmopolitan.



Conochilus sp. Ehrenberg: Fig. 80, colony; *Pompholyx* sp. Gosse: Fig. 81, dorsal view; *Testudinella patina* (Hermann): Fig. 82, ventral view; *Filinia longiseta* (Ehrenberg): Fig. 83, lateral view; *Philodina* sp. (Ehrenberg): Fig. 84, dorsal view; *Rotaria* sp. Scopoli: Fig. 85, lateral view.

57. *Testudinella patina* (Hermann, 1783) (Fig. 82)

Characters: Lorica almost circular, transparent and dorsoventrally flattened. Dorsal plate slightly convex and anterior dorsal margin rounded. Lateral antennae situated anterior to middle region of lorica. Foot opening circular and located in the middle part on the ventral side; foot annulated projecting with a terminal ciliated cap.

Distribution: Bhutan-Trashiyangtse, Trashigang and Bumthang districts at Sites 1,3 and 15
Sub-continent- India (Meghalaya, Assam, West Bengal, Orissa, Bihar, Andhra Pradesh, Gujarat, Punjab and Kashmir)

Elsewhere – Cosmopolitan

Family: **Filinidae** Bartos, 1959

58. *Filinia longiseta* (Ehrenberg, 1834) (Fig. 83)

Characters: Body barrel-shaped with two antero-lateral and long posterior setae. Anterior setae usually folded ventrally. Posterior seta inserted usually 25 µm away from caudal end of body.

Distribution: Bhutan - Trashigang, Thimphu and Paro districts at Sites 4, 5, and 13
Sub-continent- India (Meghalaya, Assam, West Bengal, Bihar, Orissa, Madhya Pradesh, Gujarat, Rajasthan, Punjab, Haryana and Jammu)

Elsewhere – Cosmopolitan

Order: **Bdelloidea** Remane, 1933

Family: **Philodinidae** Remane, 1933

59. *Philodina* sp. (Ehrenberg, 1832) (Fig. 84)

Characters: Body elongated; divided into smaller head, cervical and foot segments; foot segmented with two short spurs and four toes.

Distribution: Bhutan - Trashiyangtse, Trashigang, Samdrup Jongkhar and Samtse at Sites 1, 2, 3, 6, 9 and 11.

Sub-continent- India

Elsewhere – Cosmopolitan

60. *Rotaria* sp. Scopoli, 1777 (Fig. 85)

Characters: Body long, slender and fusiform. Palp-like antennae on first neck segment. Trunk long. Slender and telescopic with a pair of spurs; last foot-segment with slender toes.

Distribution: Bhutan - Samdrup Jongkhar at Site 9

Sub-continent- India (Meghalaya, Assam, West Bengal, Bihar, Orissa and Andhra Pradesh)

Elsewhere – Cosmopolitan.

C. QUANTITATIVE ABUNDANCE

Annual variations in ranges and mean values of population densities of net plankton, phytoplankton, zooplankton and their various groups are presented in Tables: 16-18 at three sites respectively. In addition, species composition and monthly variations in population density of different phytoplankton and zooplankton species observed in two annual cycles (February 2000-January 2002) at three study sites are indicated in Tables: 19-24. Quantitative abundance of net plankton, phytoplankton and zooplankton showed considerable monthly variations at different sites as described below:

Net Plankton: Net plankton abundance at Site 1 (pond) ranged between 93-1114 n/l (286 ± 227 n/l) and at Site 2 (peat bog) and 3 (paddy-field) between 93-692 n/l (245 ± 136 n/l) and 75-663 n/l (247 ± 138 n/l) respectively. At Sites 1 and 2, annual ranges and mean values of net plankton were significantly higher during the first year but a reverse trend was observed in the paddy-field (Fig. 107).

Temporal variations of net plankton density at Site 1 (pond) exhibited notable differences in their ranges and mean values between the two years of study period. It registered significantly wide range and higher mean i.e., between 93-1114 n/l (344 ± 306 n/l) in the first year than the one during the second year i.e., between 102-339 n/l (228 ± 85 n/l). Further, the density remained low from June-October during the study period. Net plankton depicted a bimodal pattern with a distinct peak in April and minima in September during first year and their secondary maxima (310 n/l) was registered in November. After a sharp decline during January (95 n/l), the net plankton continued to increase and attained primary maxima in March during the second year. They registered generally low density during June-October, which, in turn, increased and registered secondary maxima during December and January (289 n/l each) during the second annual cycle.

At Site 2 (peat bog), temporal variations of net plankton density depicted a wider range between 93-692 n/l (289 ± 179 n/l) during the first year and between 150-280 n/l (201 ± 50 n/l) in the second year with bimodal patterns of fluctuations. In general lower density was observed prior to monsoon during the study period. A distinct peak was registered in August and minima in January during the first year of the study. Their abundance declined sharply from September-October and subsequently increased to attain secondary maxima (322 n/l) in December. However, in the second year, primary maxima was noticed in July, while secondary maxima was registered in December (241 n/l).

TABLE 16: TEMPORAL VARIATIONS OF PLANKTON AT SITE 1 (POND)

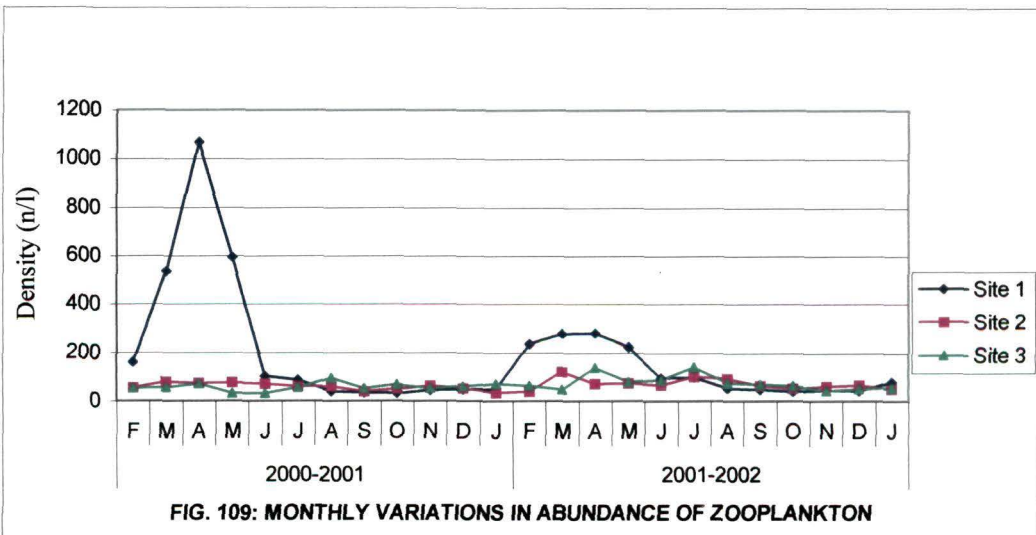
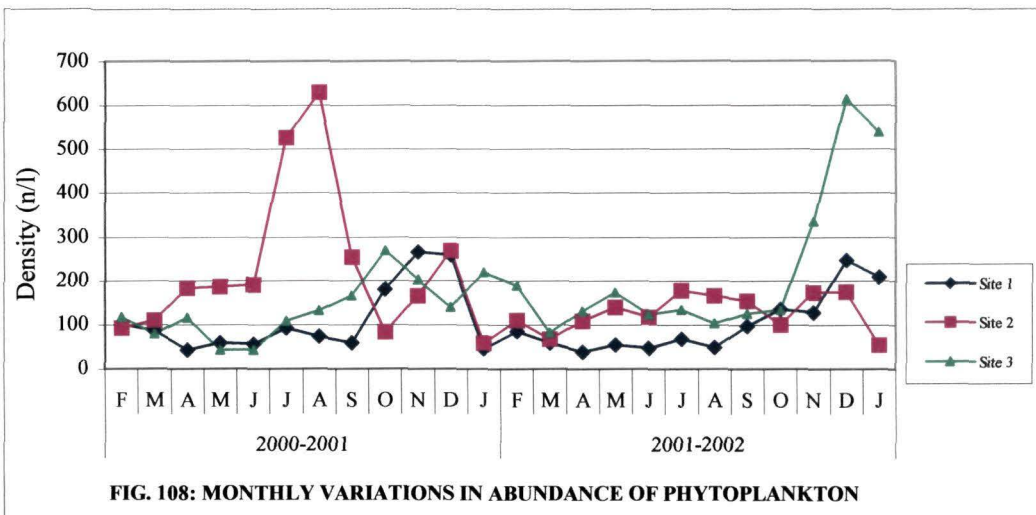
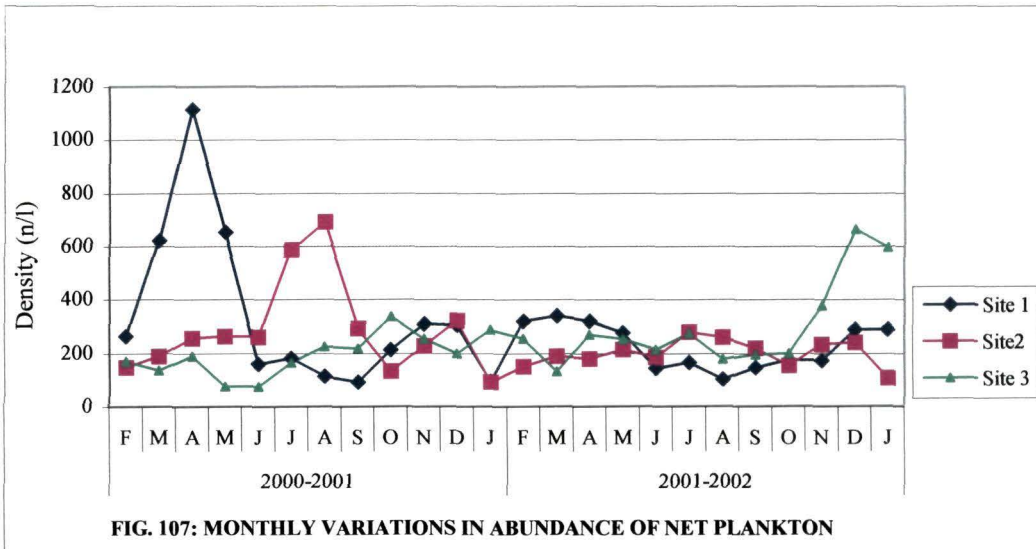
Biotic factors	First year	Second year	Study period
Net Plankton (n/l)	93-1114 (344 ± 306)	102-339 (228 ± 85)	93-1114 (286 ± 227)
Phytoplankton			
Qualitative	26 Species: Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyceae		
Species Richness	8-14	6-12	6-14
Percentage similarity	22.2-80.0	21.1-100.0	21.1-100.0
Quantitative	Bacillariophyceae > Cyanophyceae > Chlorophyceae > Euglenophyceae		
Abundance (n/l)	43-265 (110 ± 80)	38-246 (101 ± 67)	38-265 (106 ± 72)
Percentage Composition	3.9-85.5 (48.3 ± 29.3)	11.9-85.1 (47.7 ± 26.4)	3.9-85.5 (48.0 ± 27)
Species Diversity			
(i) Shannon's index	1.257-2.429 (1.971 ± 0.36)	1.305-2.157 (1.9 ± 0.517)	1.257-2.429 (1.86 ± 0.354)
(ii) Menhinick's index	0.553-1.938 (1.239 ± 0.46)	0.516-1.586 (1.094 ± 0.424)	0.516-1.938 (1.167 ± 0.439)
Dominance			
(i) Berger-Parker's index	0.169-0.698 (0.346 ± 0.168)	0.235-0.598 (0.388 ± 0.112)	0.169-0.698 (0.367 ± 0.141)
(ii) Simpson's index	0.098-0.496 (0.207 ± 0.129)	0.138-0.331 (0.232 ± 0.093)	0.098-0.496 (0.219 ± 0.111)
Evenness (E ₁)	0.482-1.009 (0.781 ± 0.18)	0.342-1.199 (0.869 ± 0.272)	0.342-1.199 (0.825 ± 0.23)
Chlorophyceae (n/l)	7-59 (22 ± 15)	4-31 (20 ± 9)	4-59 (21 ± 12)
Bacillariophyceae (n/l)	12-98 (48 ± 27)	13-103 (44 ± 24)	12-103 (46 ± 25)
Cyanophyceae (n/l)	0-184 (39 ± 66)	0-123 (37 ± 47)	0-184 (38 ± 56)
Euglenophyceae (n/l)	0-4 (1 ± 1)	-	0-4 (1 ± 1)
Zooplankton			
Qualitative	51 species: Rotifera > Cladocera > Rhizopoda > Copepoda > Ostracoda = Nematoda		
Species Richness	12-28	10-24	10-28
Percentage similarity	21.4-77.6	20.0-90.0	20.0-90.0
Quantitative	Copepoda > Cladocera > Rotifera > Rhizopoda > Nematoda > Ostracoda = Gastrotricha		
Abundance (n/l)	33-1071 (234 ± 328)	43-282 (127 ± 98)	33-1071 (180 ± 243)
Percentage Composition	14.5-96.1 (51.6 ± 29.3)	14.9-88.1 (52.3 ± 26.4)	14.5-96.1 (52.0 ± 27.3)
Species Diversity			
(i) Shannon's index	0.93-3.232 (2.278 ± 0.82)	1.149-3.139 (2.335 ± 0.86)	0.93-3.232 (2.306 ± 0.82)
(ii) Menhinick's index	0.458-2.746 (1.85 ± 0.796)	0.598-2.858 (1.836 ± 0.82)	0.458-2.858 (1.843 ± 0.79)
Dominance			
(i) Berger-Parker's index	0.184-0.793 (0.433 ± 0.208)	0.2-0.815 (0.467 ± 0.25)	0.184-0.815 (0.45 ± 0.227)
(ii) Simpson's index	0.102-0.673 (0.355 ± 0.223)	0.111-0.779 (0.364 ± 0.262)	0.102-0.779 (0.36 ± 0.238)
Evenness (E ₁)	0.343-1.134 (0.813 ± 0.303)	0.405-1.096 (0.833 ± 0.267)	0.343-1.134 (0.823 ± 0.28)
Rotifera (n/l)	6-21 (11 ± 4)	6-19 (11 ± 4)	6-21 (11 ± 4)
Cladocera (n/l)	7-110 (27 ± 31)	11-46 (26 ± 13)	7-110 (27 ± 22)
Copepoda (n/l)	6-950 (187 ± 304)	9-223 (81 ± 93)	6-950 (143 ± 227)
Rhizopoda (n/l)	2-18 (8 ± 5)	3-11 (7 ± 3)	2-18 (7 ± 4)
Ostracoda (n/l)	0-3 (1 ± 1)	0-3 (1 ± 1)	0-3 (1 ± 1)
Nematoda (n/l)	0-3 (1 ± 1)	1-2 (1 ± 1)	0-3 (1 ± 1)
Gastrotricha (n/l)	-	0-3 (1 ± 1)	0-3 (1 ± 1)

TABLE 17: TEMPORAL VARIATIONS OF PLANKTON AT SITE 2 (PEAT BOG)

Biotic factors	First year	Second year	Study period
Net Plankton (n/l)	93-692 (289 ± 179)	150-280 (201 ± 50)	93-692 (245 ± 136)
Phytoplankton			
Qualitative	27 species: Chlorophyceae > Bacillariophyceae > Cyanophyceae > Euglenophyceae = Dinophyceae		
Species Richness	6-12	5-16	5-16
Percentage similarity	32.0-90.9	13.3-95.2	13.3-95.2
Quantitative	Chlorophyceae > Cyanophyceae > Bacillariophyceae > Euglenophyceae > Dinophyceae		
Abundance (n/l)	59-630 (229 ± 177)	55-178 (129 ± 42)	55-630 (179 ± 136)
Percentage Composition	58.2-91.0 (73.6 ± 11.4)	35.3-73.9 (63.4 ± 10.8)	35.3-91.0 (68.5 ± 12.0)
Species Diversity			
(i) Shannon's index	1.489-2.882 (2.429 ± 0.41)	0.961-2.658 (1.644 ± 0.493)	0.961-2.882 (2.046 ± 0.59)
(ii) Menhinick's index	0.359-1.049 (0.764 ± 0.226)	0.447-1.482 (0.877 ± 0.29)	0.359-1.483 (0.82 ± 0.26)
Dominance			
(i) Berger-Parker's index	0.262-0.784 (0.414 ± 0.128)	0.225-0.809 (0.486 ± 0.178)	0.225-0.809 (0.45 ± 0.156)
(ii) Simpson's index	0.172-0.619 (0.266 ± 0.118)	0.128-0.666 (0.315 ± 0.17)	0.128-0.666 (0.029 ± 0.145)
Evenness (E ₁)	0.564-1.386 (1.077 ± 0.209)	0.536-0.96 (0.739 ± 0.19)	0.536-1.386 (0.908 ± 0.24)
Chlorophyceae (n/l)	15-274 (107 ± 84)	40-109 (74 ± 27)	15-274 (90 ± 63)
Bacillariophyceae (n/l)	13-226 (947 ± 58)	2-58 (26 ± 18)	2-226 (36 ± 34)
Cyanophyceae (n/l)	2-335 (72 ± 104)	3-75 (26 ± 19)	2-335 (49 ± 77)
Euglenophyceae (n/l)	0-9 (6 ± 3)	0-5 (4 ± 1)	0-9 (5 ± 2)
Dinophyceae (n/l)	0-6 (4 ± 2)	0-5 (5 ± 1)	0-6 (4 ± 2)
Zooplankton			
Qualitative	50 species: Rotifera > Cladocera > Rhizopoda > Copepoda > Ostracoda = Nematoda		
Species Richness	14-28	12-29	12-29
Percentage similarity	33.3-87.3	23.5-91.9	23.5-91.9
Quantitative	Cladocera > Rotifera > Copepoda = Rhizopoda > Ostracoda = Nematoda		
Abundance (n/l)	34-79 (60 ± 14)	40-123 (72 ± 23)	34-123 (66 ± 20)
Percentage Composition	10.4-41.8 (26.4 ± 11.4)	26.1-64.7 (36.7 ± 10.8)	10.4-64.7 (31.5 ± 12.02)
Species Diversity			
(i) Shannon's index	2.508-3.04 (2.732 ± 0.188)	1.871-3.24 (2.758 ± 0.38)	1.871-3.24 (2.745 ± 0.3)
(ii) Menhinick's index	2.041-3.255 (2.519 ± 0.384)	1.172-2.871 (2.428 ± 0.49)	1.172-3.255 (2.474 ± 0.42)
Dominance			
(i) Berger-Parker's index	0.14-0.253 (0.179 ± 0.043)	0.108-0.488 (0.19 ± 0.11)	0.108-0.488 (0.185 ± 0.084)
(ii) Simpson's index	0.046-0.094 (0.069 ± 0.01)	0.037-0.267 (0.079 ± 0.07)	0.037-0.267 (0.074 ± 0.05)
Evenness (E ₁)	0.875-0.957 (0.927 ± 0.03)	0.729-0.967 (0.922 ± 0.07)	0.729-0.967 (0.925 ± 0.05)
Rotifera (n/l)	7-22 (14 ± 4)	5-30 (17 ± 7)	5-30 (15 ± 6)
Cladocera (n/l)	6-27 (15 ± 7)	9-80 (25 ± 9)	6-80 (20 ± 15)
Copepoda (n/l)	4-33 (14 ± 8)	9-27 (13 ± 5)	4-33 (14 ± 7)
Rhizopoda (n/l)	9-28 (15 ± 6)	4-32 (14 ± 8)	4-32 (14 ± 7)
Ostracoda (n/l)	0-3 (2 ± 1)	0-3 (2 ± 1)	0-3 (2 ± 1)
Nematoda (n/l)	0-3 (2 ± 1)	-	0-4 (2 ± 1)

TABLE 18: TEMPORAL VARIATIONS OF PLANKTON AT SITE 3 (PADDY-FIELD)

Biotic factors	First year	Second year	Study period
Net Plankton (n/l)	75-338 (195 ± 79)	130-663 (300 ± 166)	75-663 (247 ± 138)
Phytoplankton			
Qualitative	35 species: Chlorophyceae > Bacillariophyceae > Cyanophyceae > Euglenophyceae > Chrysophyceae = Dinophyceae		
Species Richness	8-16	13-18	8-18
Percentage similarity	24.0-85.7	24.0-87.5	24.0-87.5
Quantitative	Bacillariophyceae > Cyanophyceae > Chlorophyceae > Euglenophyceae > Chrysophyceae = Dinophyceae		
Abundance (n/l)	43-268 (136 ± 69)	82-613 (223 ± 177)	43-613 (180 ± 139)
Percentage Composition	57.3-79.6 (67.1 ± 8.9)	48.5-92.5 (68.6 ± 15.2)	48.5-92.5 (67.9 ± 12.2)
Species Diversity			
(i) Shannon's index	1.271-2.407 (1.881 ± 0.41)	0.851-2.404 (1.952 ± 0.52)	0.851-2.394 (1.916 ± 0.46)
(ii) Menhinick's index	0.743-1.913 (1.202 ± 39)	0.646-1.675 (1.154 ± 33)	0.646-1.913 (1.178 ± 0.35)
Dominance			
(i) Berger-Parker's index	0.253-0.693 (0.429 ± 0.142)	0.111-0.816 (0.4 ± 0.214)	0.111-0.816 (0.414 ± 0.18)
(ii) Simpson's index	0.11-0.492 (0.248 ± 0.124)	0.039-0.671 (0.241 ± 0.2)	0.039-0.671 (0.245 ± 0.16)
Evenness (E ₁)	0.485-0.884 (0.745 ± 0.145)	0.307-0.868 (0.72 ± 0.193)	0.307-0.938 (0.732 ± 0.17)
Chlorophyceae (n/l)	4-61 (25 ± 18)	23-88 (46 ± 23)	4-88 (35 ± 23)
Bacillariophyceae (n/l)	12-237 (91 ± 72)	35-99 (75 ± 24)	12-237 (83 ± 53)
Chrysophyceae (n/l)	0-3 (1 ± 1)	0-3 (1 ± 1)	0-3 (1 ± 1)
Cyanophyceae (n/l)	0-85 (16 ± 23)	0-500 (100 ± 178)	0-500 (58 ± 131)
Euglenophyceae (n/l)	0-15 (4 ± 5)	0-15 (2 ± 4)	0-15 (3 ± 5)
Dinophyceae (n/l)	0-3 (1 ± 1)	-	0-3 (1 ± 1)
Zooplankton			
Qualitative	54 species: Rotifera > Cladocera > Rhizopoda > Copepoda > Ostracoda = Nematoda = Gastrotricha		
Species Richness	13-26	13-27	13-27
Percentage similarity	43.2-90.2	41.2-82.8	41.2-90.2
Quantitative	Rotifera > Cladocera > Copepoda = Rhizopoda > Ostracoda = Nematoda = Gastrotricha		
Abundance (n/l)	32-95 (59 ± 17)	42-140 (76 ± 32)	32-140 (68 ± 27)
Percentage Composition	20.4-43.4 (32.9 ± 8.9)	7.54-51.5 (31.2 ± 15.2)	7.54-51.5 (32.1 ± 12.2)
Species Diversity			
(i) Shannon's index	2.662-3.138 (2.229 ± 0.26)	2.397-3.054 (2.809 ± 0.2)	2.397-3.676 (2.904 ± 0.249)
(ii) Menhinick's index	1.768-3.467 (2.854 ± 0.52)	1.838-3.175 (2.439 ± 0.42)	1.768-3.467 (2.647 ± 0.51)
Dominance			
(i) Berger-Parker's index	0.077-0.143 (0.112 ± 0.02)	0.107-0.329 (0.167 ± 0.07)	0.077-0.329 (0.14 ± 0.06)
(ii) Simpson's index	0.03-0.063 (0.04 ± 0.01)	0.042-0.122 (0.065 ± 0.03)	0.03-0.122 (0.05 ± 0.02)
Evenness (E ₁)	0.95-1.142 (0.983 ± 0.05)	0.853-0.988 (0.934 ± 0.04)	0.853-1.142 (0.959 ± 0.05)
Rotifera (n/l)	10-54 (22 ± 12)	9-58 (21 ± 4)	9-58 (21 ± 13)
Cladocera (n/l)	8-24 (16 ± 6)	13-44 (21 ± 9)	9-44 (18 ± 8)
Copepoda (n/l)	5-15 (8 ± 3)	6-55 (18 ± 14)	5-55 (13 ± 11)
Rhizopoda (n/l)	5-23 (12 ± 5)	7-24 (14 ± 4)	5-24 (13 ± 5)
Ostracoda (n/l)	0-2 (1 ± 1)	0-3 (1 ± 1)	0-3 (1 ± 1)
Nematoda (n/l)	0-6 (1 ± 2)	0-5 (1 ± 2)	0-6 (1 ± 2)
Gastrotricha (n/l)	0-2 (1 ± 1)	0-1 (1 ± 1)	0-2 (1 ± 1)



At Site 3 (paddy-field), monthly variations in net plankton abundance exhibited a narrow range between 75-338 n/l (195 ± 79 n/l) in first year and a significantly wider range and higher mean between 130-663 n/l (300 ± 166 n/l) during the second year. It depicted a broadly trimodal pattern of monthly fluctuation with relatively higher net plankton density during the paddy season till post-paddy season. Small tertiary maxima (189 n/l) was recorded in April, which was followed by a decline between May-June (75 n/l and 76 n/l respectively) during the first year. Further, their density gradually increased during July-October to register primary maxima in the first year in the paddy-field. A sharp decline in the next two months was followed by a marginal increase in January to attain secondary maxima (290 n/l). However, during the second annual cycle of the study period, two maxima of almost equal magnitude were registered during April (270 n/l) and July (274 n/l) while the period from August-October exhibited low density but it increased sharply from November-December and culminated into a distinct peak.

Phytoplankton: Temporal variations in quantitative abundance of phytoplankton at Site 1 (pond) exhibited a narrow range and low mean between 38-265 n/l (06 ± 72 n/l). However at Site 2 (peat bog) and Site 3 (paddy-field), wider ranges and higher mean values were observed i.e., between 55-630 n/l (179 ± 136 n/l) and 43-613 n/l (180 ± 139 n/l) respectively depicting significant similarities in phytoplankton abundance of these two sites during the study period (Fig. 108).

Annual ranges and mean values of abundance were identical at Site 1 and depicted broadly a unimodal pattern of monthly fluctuation. Phytoplankton density remained generally low from February-September (38-97 n/l) during both the years. Maxima (265 n/l) abundance was depicted in November during the first year and peak (246 n/l) in December during the second year while minima was recorded in April 2001. In this ecosystem, phytoplankton contributed between 3.86-85.5% ($48 \pm 27.3\%$) of net plankton; maximum and minimum percentage contribution was noticed during November and April 2000 respectively. Phytoplankton density dominated over zooplankton between July-December (51.1-85.5%) in the first year and September-January (66.9-85.1%) in the second year. Further, their percentage composition varied more widely between 3.9-85.5% ($48.3 \pm 29.3\%$) in the first year and relatively less widely between 11.8-85.1 ($47.7 \pm 26.4\%$) in the second year.

At Site 2 (peat bog), significant variations in mean and ranges between two annual cycles was observed depicting a wider fluctuation of phytoplankton density in the first year i.e., between 59-630 n/l (229 ± 177 n/l) and a significantly narrow range in the second year i.e., between 55-178 n/l (129 ± 42 n/l). Further, they depicted a bimodal pattern in first year but a broadly multimodal in the succeeding year. The density gradually increased from February to a peak in August during the first year. After a sharp decline between September-October there was marginal increase and secondary maxima (268 n/l) was registered in December, which, in turn, was followed by a minima (55 n/l) in January. During the second year, there was a very gradual increase from February-July when first maxima occurred (178 n/l) and the period from August-October depicted gradual decline followed by a marginal increase to attain second maxima in December (175 n/l). Phytoplankton constituted significant percentage of net plankton during all the months except during March 2001. Phytoplankton comprised between 35.3-91.0% ($31.5 \pm 12.0\%$) of net plankton during the study period. Further, percentage composition differed broadly between the two years of study i.e., between 58.2-91.0% ($73.6 \pm 11.4\%$) and 35.3-73.9 % ($63.4 \pm 10.8\%$) respectively.

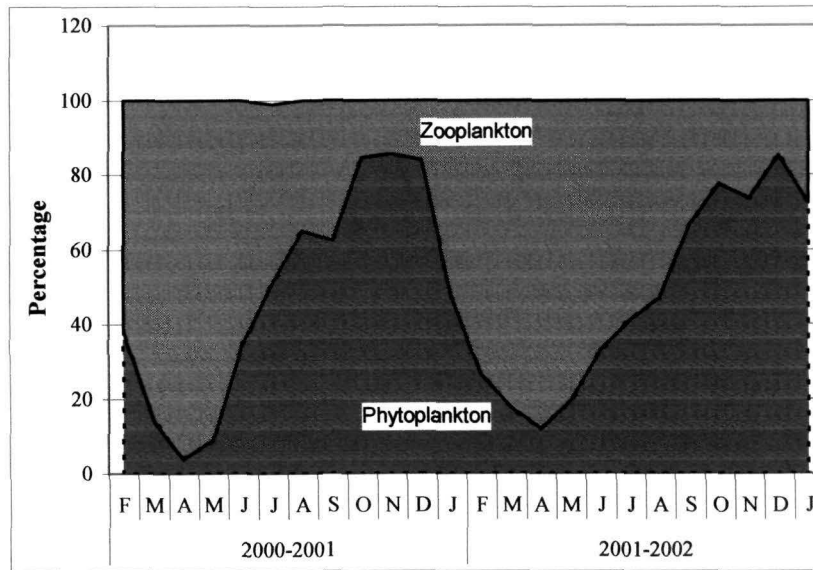
At Site 3, temporal variations in phytoplankton abundance (Table: 17) depicted considerably wider range and higher mean during the second year of study i.e., between 82-613 n/l (223 ± 177 n/l). In the first year, narrow range with low mean between 43-268 n/l (136 ± 69 n/l) was recorded but with broadly bimodal pattern of their monthly variations during both the years. During the first year, their density remained generally low till June (minima) and gradually increased and registered primary maxima in October while secondary maxima was recorded in January (218 n/l). During the second year, there was a small maxima in May (173 n/l), a marginal decline till August and subsequently sharp increase during October-December depicting a distinct peak. Phytoplankton (Fig. 110) comprised between 48.5-92.5 % ($67.8 \pm 12.2\%$) of net plankton during the study period, with contribution to net plankton abundance being distinctly higher than zooplankton in most of the months except April (48.5 %) and July (48.9 %). Further, their percentage composition in the two years differed marginally and ranged between 57.3-79.6 (77.1 ± 8.8 %) and 48.5-92.5 ($68.5 \pm 15.2\%$) respectively.

Species diversity of phytoplankton at three sites (Site 1-3) ranged between 1.257-2.429 (1.86 ± 0.354), 0.961-2.882 (2.046 ± 0.589) and 0.851-2.394 (1.916 ± 0.456)

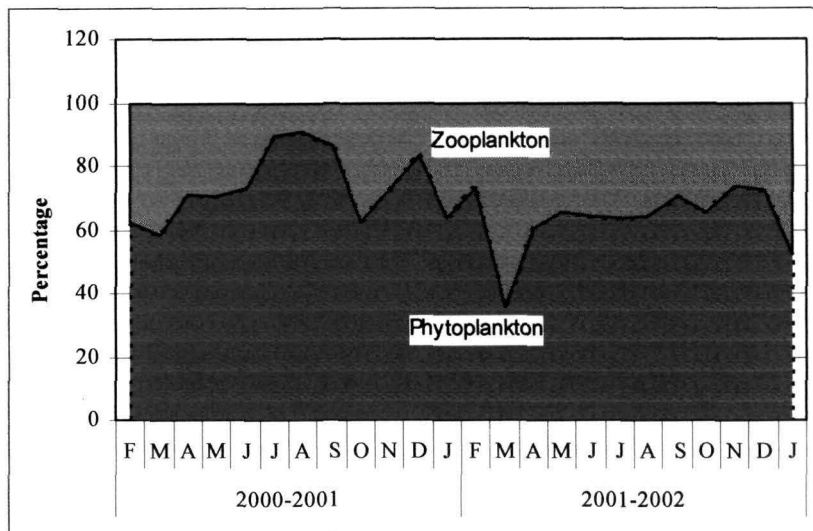
respectively (Table: 15-17) *vide* Shannon's index (H'). Further species diversity computed *vide* Menhinick's index (D_{mn}) corresponded broadly with H' but ranged within lower values i.e., between 0.516-1.938 (1.167 ± 0.430), 0.359-1.483 (0.82 ± 0.262) and 0.646-1.913 (1.178 ± 0.353) at three sites respectively. Maximum diversity was recorded at Site 2 (peat bog) in May during the first year of the study and the minimum diversity at Site 3 (paddy-field) in December during the second year.

Further, at Site 1 (pond), annual variations in range and mean values between the two annual cycles of the study period were identical with bimodal pattern of monthly fluctuation (Fig.111) during the first year and unimodal during second year. Peak diversity in first year and primary maxima of species diversity in second year were both registered in July with generally higher diversity in pre-monsoon and during peak monsoon periods at this site. However in both the years there was decline in the diversity from October-December. At Site 2, phytoplankton diversity fluctuated with relatively narrow range but with higher mean during the first year between 1.489-2.882 (2.429 ± 0.405) and with wider range and lower mean in the second year between 0.961-2.658 (1.644 ± 0.493) *vide* Shannon's index, following broadly a bimodal pattern of monthly fluctuation. Higher diversity was seen generally during warmer months from April-September with peak value registered in May in the first year and primary maxima in July in second year. The minima was recorded in October during the second year. There was slight increase in phytoplankton species diversity after November and registered a secondary maxima during January in the first year (2.468) as well as in second year (1.944). In the paddy-field (Site 3), there was a significant difference in ranges between the two years even though the mean values remained identical. The diversity of phytoplankton among different months in this ecosystem fluctuated with narrow range during the first year between 1.271-2.407 and with wider range during the second year between 0.851-2.404. Further, it followed a multimodal pattern of temporal variations during the study period depicting peak (2.407) in March of first year and with several maxima during second year i.e., in May (2.404), August (2.350) and January (1.074). The diversity during October-December was generally low with minima depicted in December (0.851) in second year.

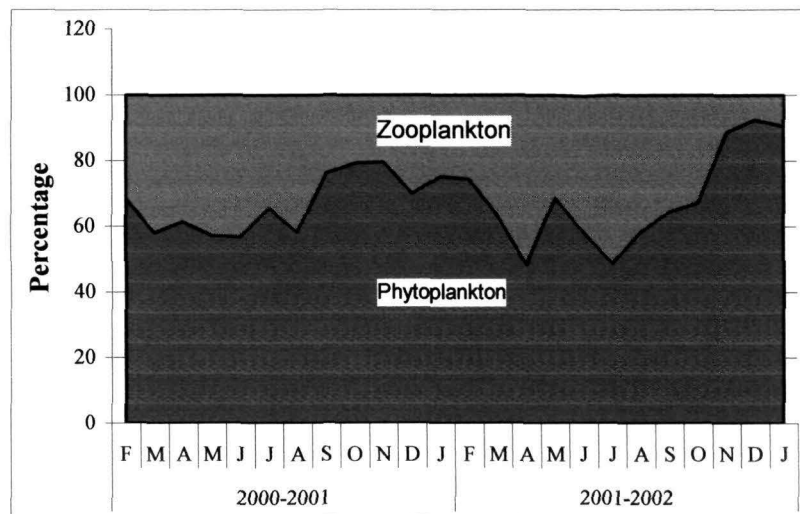
The dominance of phytoplankton (Table 15-17) at three sites ranged between 0.098-0.496 (0.219 ± 0.111), 0.128-0.666 (0.290 ± 0.145) and 0.039-0.671 (0.245 ± 0.160) *vide* Simpson's index (λ) and corresponded broadly with Berger-Parker's index (d), which, in



Site 1



Site 2



Site 3

FIG. 110: MONTHLY VARIATIONS IN PERCENTAGE COMPOSITION OF PHYTOPLANKTON AND ZOOPLANKTON

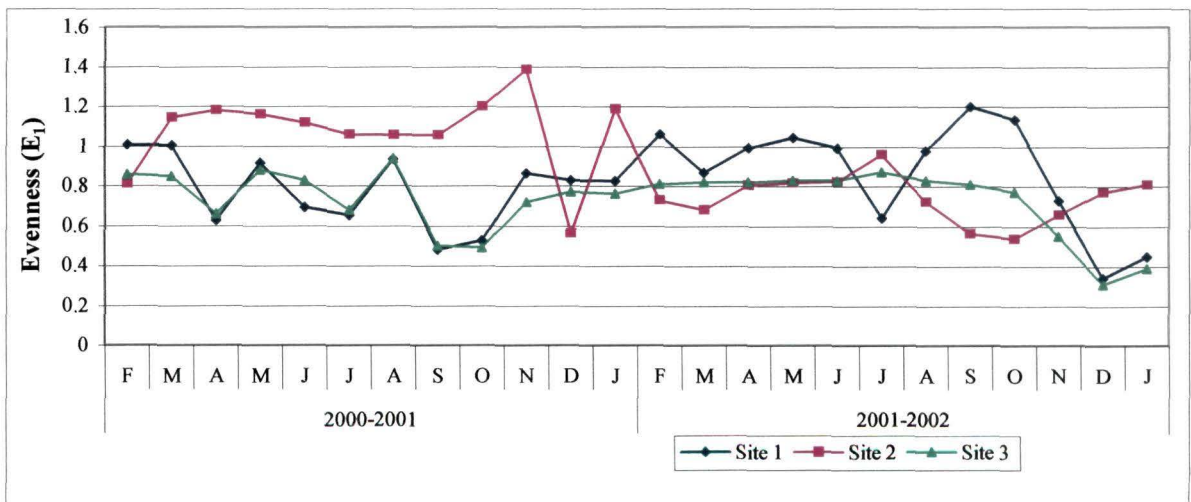
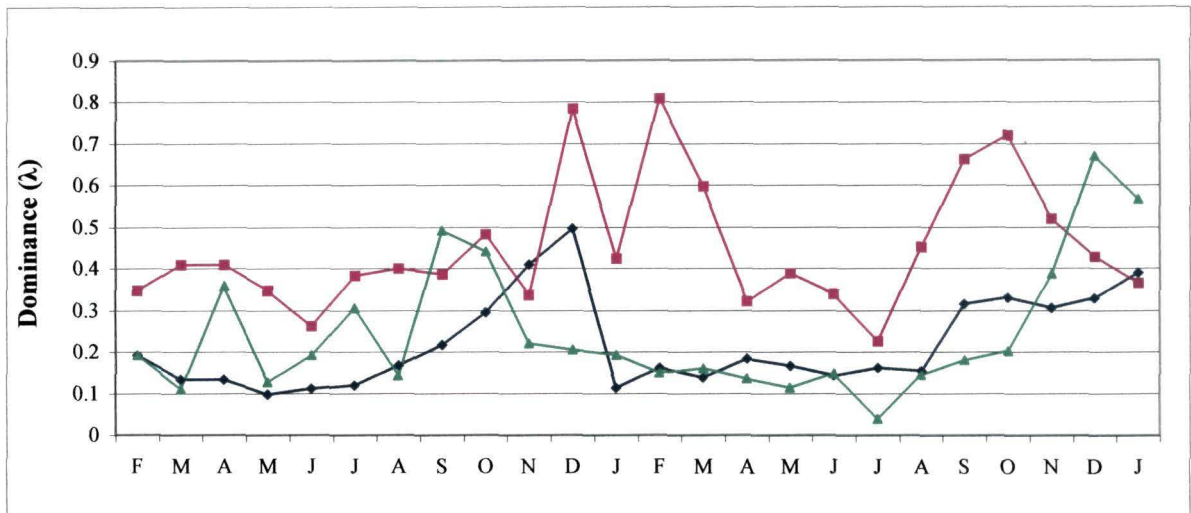
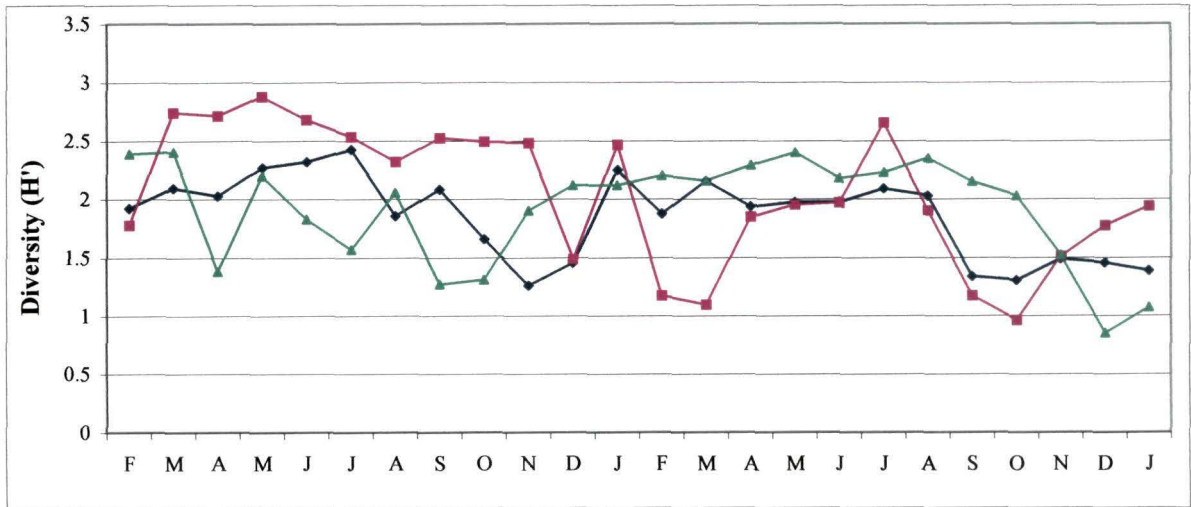


FIG. 111: MONTHLY VARIATIONS OF SPECIES DIVERSITY, DOMINANCE AND EVENNESS OF PHYTOPLANKTON

turn, ranged with proportionately higher values between 0.169-0.698 (0.367 ± 0.141), 0.225-0.809 (0.450 ± 0.1560) and 0.111-0.816 (0.414 ± 0.178) respectively during the study period. Highest and lowest species dominance were seen at Site 3 (paddy-field) in December and July during the second year respectively. At Site 1 (pond), a distinct unimodal pattern of monthly fluctuation was observed during the study period, with the first year exhibiting wider range between 0.098-0.496 than second year (0.138-0.331) *vide* Simpson's index, while mean values remained identical. Further, phytoplankton dominance in this water body was generally low during the monsoon. The peak (0.496) was registered in December in the first year and maxima of second year (0.39) in January. The minima (0.098) was recorded in May during the first year of study. At Site 2 (peat bog), there was no significant difference between ranges and mean values between the two years. However, a unimodal pattern of monthly fluctuations of phytoplankton dominance in the first year and a bimodal in the second year of study were observed in this ecosystem. A long period between February-November during the first year depicted very marginal fluctuation with generally low phytoplankton dominance (0.172-0.298) followed by a slight increase in December to attain maxima (0.619). After a sharp decline again in January it increased to depict peak (0.666) in February during the second year of the study. There was further decline to minima in July and increased again from August-October and registered secondary maxima (0.54) in October. Temporal variations of phytoplankton dominance at Site 3 fluctuated with a narrow range during the first year between 0.110-0.492 (0.248 ± 0.124) and with a wider range during second year between 0.039-0.671 (0.241 ± 0.195) *vide* Simpson's index. Further, a trimodal pattern of fluctuation in the first year and a unimodal in the second year was registered in this ecosystem. During the first year, April (0.359), July (0.306) and September (0.492) exhibited maxima in phytoplankton dominance and the peak (0.671) was registered during December. Generally lower dominance was recorded during the early part of the paddy season (June-July) with minima (0.039) in July 2001.

Evenness (E_1) of phytoplankton computed at three sites exhibited relatively narrower range and lower mean values at Sites 1 (pond) and 3 (paddy-field) i.e., between 0.342-1.199 (0.825 ± 0.23) and 0.307-0.938 (0.732 ± 0.167) respectively. However at Site 2 (peat bog), it ranged more widely between 0.536-1.386 (0.908 ± 0.24) exhibiting maximum evenness during November in the first annual cycle. Similarly minimum evenness was

noted at Site 3 during December in the second year. Further, at Site 1, it fluctuated with a multimodal pattern of monthly variations in the first year and a trimodal during second year without significant differences between annual ranges and mean values. While regular fluctuations were observed in the first year, higher values were seen from February-September during the second year with maxima recorded in February (1.059), May (1.044) and September (peak). However, it declined after the monsoon to attain minima (0.342) in December. At Site 2, temporal variations in evenness of phytoplankton ranged more widely and exhibited higher mean during the first year of study between 0.564-1.386 (1.077 ± 0.209) depicting a broadly trimodal pattern while in the second year it ranged between 0.536-0.959 (0.739 ± 0.118) and depicted a bimodal pattern. Further during the first year evenness was relatively low between the period from June-October and the peak was seen in November. It remained relatively higher during this period in second year and exhibited peak in July. Secondary maxima during both the years were registered in January (1.187 and 0.811 respectively) and minima was recorded in October during the second year in this ecosystem. At Site 3, evenness of phytoplankton fluctuated abruptly between different months with no significant variations between annual ranges and mean values. Broadly multimodal pattern of its monthly variation was seen in the first year generally with higher evenness in the pre-monsoon and monsoon period, which culminated into a peak (0.94) in August. Evenness was consistently high during February-October (0.77-0.87) during the second year but it was followed by sharp decline from November-December and resulted in minima (0.39) in December.

Chlorophyceae: Temporal variations of Chlorophyceae abundance exhibited narrow ranges at Site 1 (pond) and Site 3 (paddy-field) i.e., between 4-59 n/l (21 ± 12 n/l), 4-88 n/l (35 ± 23 n/l) respectively. At Site 2 (peat bog), it depicted wider variations with high mean between 15-274 n/l (90 ± 63 n/l) during the study period. In the pond, it was the second quantitatively important group after Bacillariophyceae and varied widely in its temporal variations between two years of study with ranges and mean of 7-59 n/l (22 ± 15 n/l) in the first year and 4-31 n/l (20 ± 9 n/l) during the second year of the study. With its percentage contribution of 3.4-67.8% to total phytoplankton density, it dominated quantitatively over the other groups in the months of March and April (67.8% and 67.4% respectively) in first year and between April-June (57.4-63.2%) in the second year. Generally low abundance of

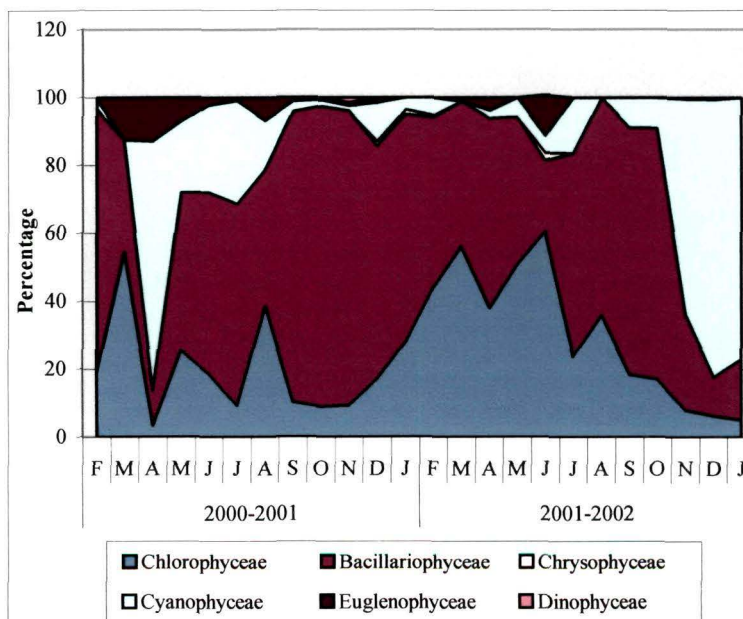
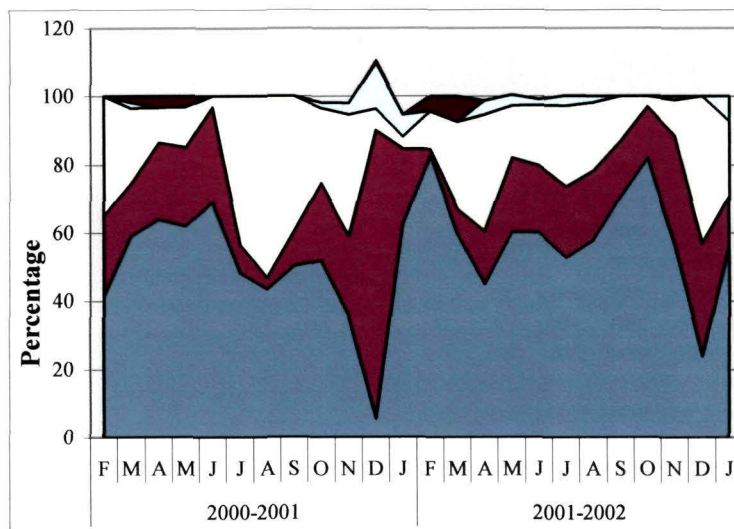
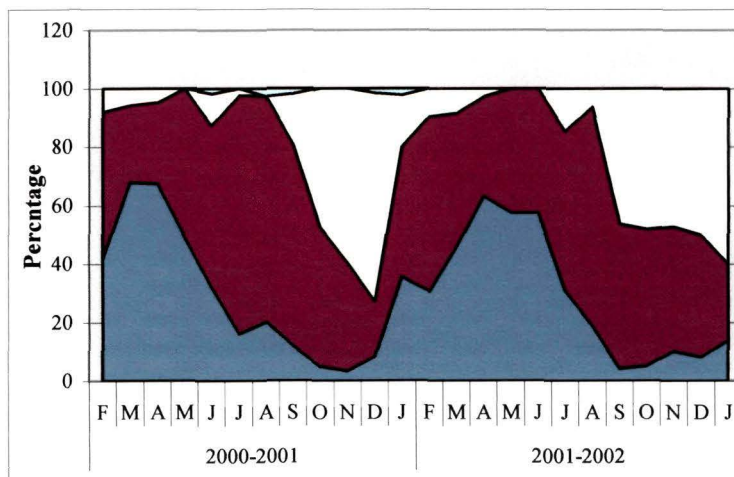


FIG. 112: MONTHLY VARIATIONS OF PERCENTAGE COMPOSITION OF VARIOUS GROUPS OF PHYTOPLANKTON

this group was recorded at this site from July-November during both the years. The peak was registered in March in the first year and minima in September 2001. Further, in this water body the filamentous algae, *Spirogyra* sp. and *Mougeotia* sp. were main contributors to an early summer maxima of Chlorophyceae. *Staurastrum* sp. (0-3 n/l) showed least abundance and was observed only in December 2001.

At Site 2 (peat bog), the density of the Chlorophyceae in different monthly collections ranged relatively more widely between 15-274 n/l (107 ± 84 n/l) whereas in the second year it ranged between 40-109 n/l (74 ± 27 n/l). The group comprised between 5.6-82.7% and was most dominant quantitatively during almost all the months except August and December in the first year and December of the second year in this ecosystem. Their density increased gradually from February till it attained maxima in August and decreased to depict minima in December during the first year. During second year there was a small maxima in the month of February (91 n/l) followed by a decline in the next month. However, the density increased again as in the first year and reached maxima of the year during September (109 n/l). Amongst members of this group, *Spirogyra* sp. was predominant (10-158 n/l) at this site and this species along with *Ulothrix* sp. were mainly responsible for summer maxima of the Chlorophyceae. All other major contributors to Chlorophyceae density including *Cosmarium* sp. (0-25 n/l) and *Desmidiium* sp. (0-20 n/l) were found more abundantly in warmer months while *Closterium setaceum* remained least abundant (0-2 n/l) at this site.

At Site 3, the Chlorophyceae constituted 5.2-60.5 % of total phytoplankton and was dominant group in the months of March during both years and during May and June in the second year. Annual ranges and mean values of this group between the two years differed significantly depicting a narrow range between 4-61 n/l (25 ± 18 n/l) in the first year and a wider range and higher mean between 23-88 n/l (46 ± 23 n/l) in the second year. Further, it depicted a bimodal pattern of monthly fluctuations during both the years. It exhibited low density from September-December with minima in April 2000 and maxima in May 2001. Amongst this group, *Scenedesmus quadricaudata* appeared in relatively higher density in late winter till pre-paddy season especially in the second year of study (18-54 n/l), while *Pediastrum* sp. showed a notable monthly fluctuation in its density with higher abundance between August-November (7-14 n/l) during both the years. Similarly, *Spirogyra* sp. (0-37 n/l) was more predominant during rainy season.

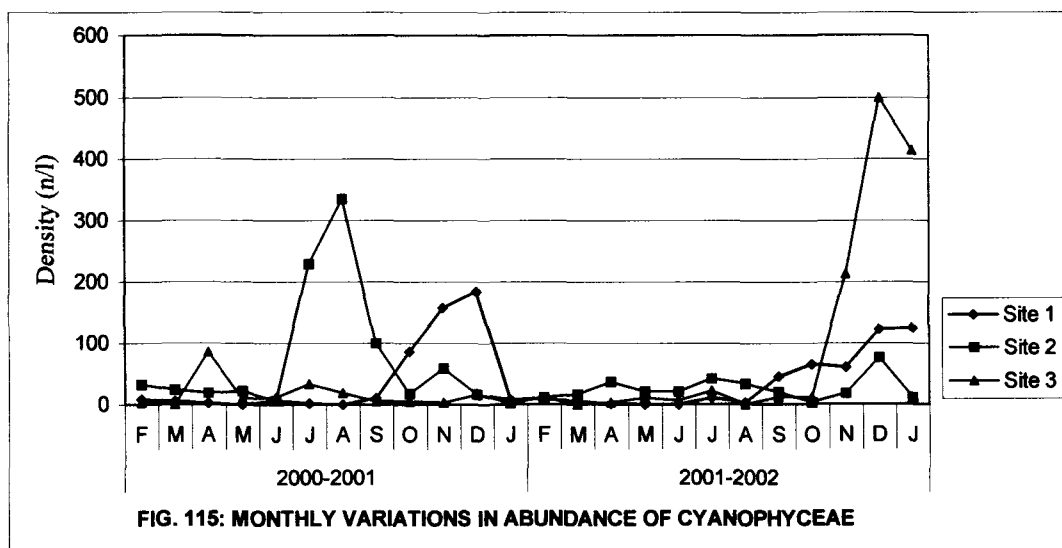
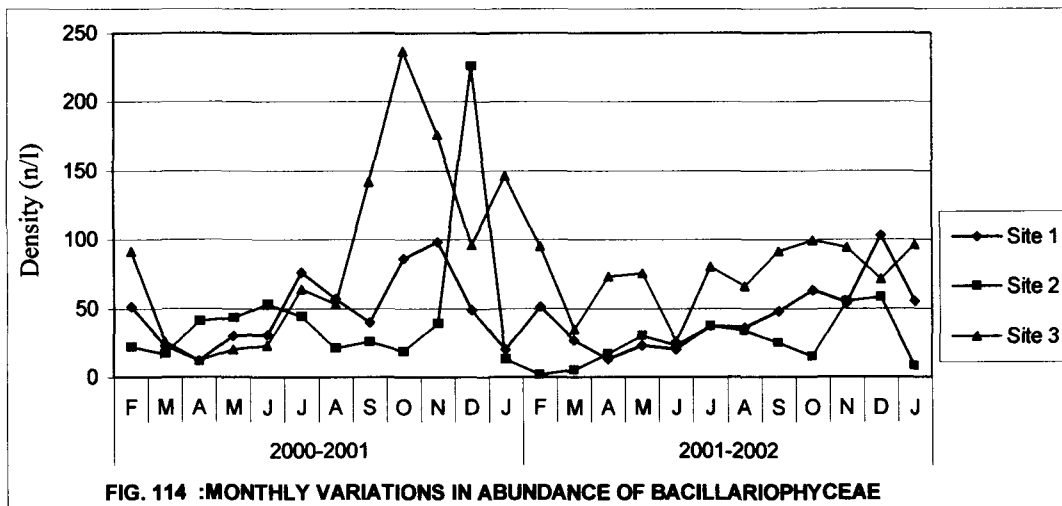
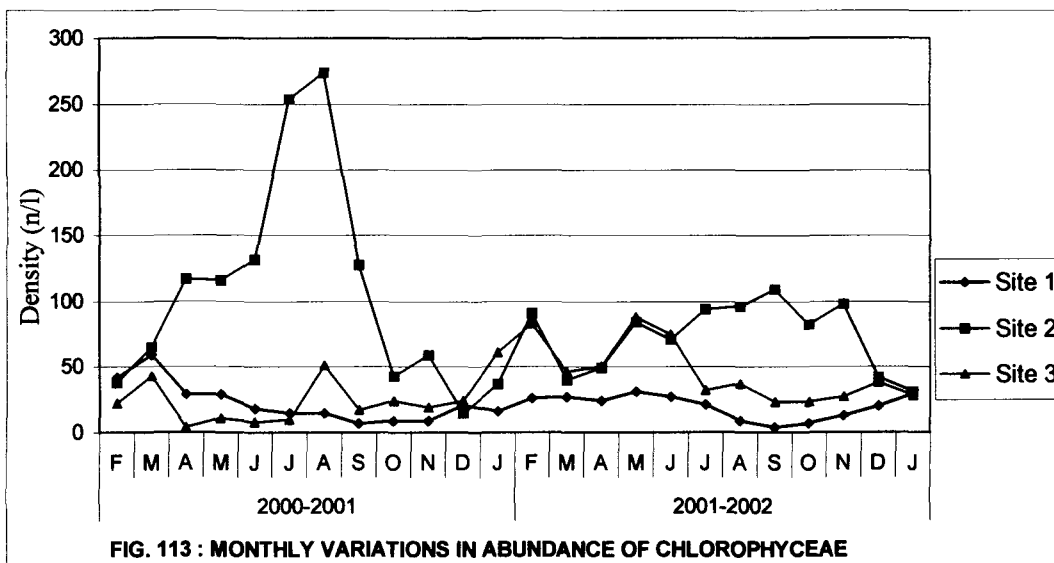


TABLE 19: MONTHLY VARIATIONS IN ABUNDANCE (n/l) OF PHYTOPLANKTON AT SITE 1 (POND)

Chlorophyceae	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
<i>Cosmarium</i> sp.	-	-	-	6	2	-	-	-	-	-	-	-	-	-	3	4	1	-	-	-	-	-	3	-
<i>Desmidium</i> sp.	-	-	-	8	6	5	1	2	-	-	-	-	-	-	2	4	6	2	-	-	-	-	2	-
<i>Micrastaerias</i> sp.	-	18	5	-	-	5	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Mougeotia</i> sp.	10	12	7	10	3	-	-	-	-	-	-	-	16	17	15	18	8	2	-	-	-	3	5	8
<i>Pleurotaenium</i> sp.	-	-	-	-	1	1	-	-	2	-	3	-	-	-	-	-	-	2	3	-	-	-	-	
<i>Pediastrum</i> sp.	-	-	-	-	-	-	1	3	-	-	7	2	-	2	-	-	-	-	2	-	-	-	3	
<i>Spirogyra</i> sp.	32	18	12	-	1	-	-	-	4	-	5	11	10	7	4	3	9	12	2	1	1	10	7	18
<i>Staurastrum</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	
<i>Ulothrix</i> sp.	-	8	5	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Volvox</i> sp.	-	3	-	2	4	4	3	2	3	9	6	3	-	1	-	2	3	3	2	3	6	-	-	
Bacillariophyceae																								
<i>Amphora</i> sp.	8	2	3	4	4	-	-	-	-	-	-	1	-	-	2	3	3	-	-	-	-	4	6	3
<i>Caloneis</i> sp.	-	-	-	2	-	-	-	3	4	-	3	2	-	-	2	1	-	-	-	-	-	1	-	
<i>Cymbella</i> sp.	-	-	-	-	5	8	12	2	10	13	4	2	-	-	1	-	2	5	4	8	10	4	1	1
<i>Diatoma</i> sp.	-	-	-	-	-	-	-	1	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Eunotia</i> sp.	-	1	-	-	-	-	-	1	-	-	-	-	2	3	-	-	-	-	-	-	-	-	-	
<i>Fragilaria</i> sp.	25	12	3	8	15	18	10	4	22	25	11	-	18	2	-	9	3	4	8	12	13	6	-	
<i>Frustulia</i> sp.	2	-	4	4	-	-	-	-	-	-	-	5	-	3	4	2	-	2	1	-	-	-	2	
<i>Navicula</i> sp.	12	8	2	4	2	15	20	25	42	55	16	5	20	11	4	8	12	23	15	28	40	35	25	18
<i>Pinnularia</i> sp.	-	-	-	-	-	15	15	1	2	1	-	1	11	4	-	-	-	3	8	-	-	-	2	
<i>Neidium</i> sp.	4	-	-	-	-	11	-	2	3	2	13	-	-	-	-	-	-	-	-	-	5	70	28	
<i>Synedra</i> sp.	-	-	-	-	-	-	-	1	2	1	-	3	-	4	-	-	-	-	-	-	-	-	1	
<i>Tabellaria</i> sp.	-	-	-	8	5	9	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	
Cyanophyceae																								
<i>Microcystis</i> sp.	-	-	-	-	6	2	-	-	-	-	4	-	-	-	-	1	-	-	-	-	-	-	-	
<i>Oscillatoria</i> sp.	8	2	-	-	-	-	-	-	86	158	180	8	3	3	-	-	-	7	2	45	65	60	120	125
<i>Phormidium</i> sp.	-	3	2	-	-	-	-	10	-	-	-	-	5	2	-	-	-	3	1	-	-	-	3	-
Euglenophyceae																								
<i>Euglena</i> sp.	-	-	-	-	1	-	2	1	-	-	4	1	-	-	-	-	-	-	-	-	-	-	-	
TOTAL PHYTOPLANKTON	101	87	43	59	56	93	74	58	181	265	258	45	85	59	38	54	47	68	48	97	135	127	246	209

TABLE 20: MONTHLY VARIATIONS IN ABUNDANCE (n/l) OF PHYTOPLANKTON AT SITE 2 (PEAT BOG)

	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
Chlorophyceae																								
<i>Closterium</i> sp.	4	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	4	1	-	-	-	-	-
<i>Closterium setaceum</i>	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
<i>Cosmarium</i> sp.	5	12	20	25	6	7	10	-	-	-	1	-	-	-	8	3	7	8	9	-	-	3	9	-
<i>Desmidium</i> sp.	4	8	10	15	20	13	3	2	3	-	-	7	-	-	2	9	11	15	8	4	6	4	5	4
<i>Euastrum</i> sp.	-	-	2	1	1	-	-	3	-	5	-	-	-	-	-	-	-	-	-	-	-	-	3	-
<i>Pleurodiscus</i> sp.	-	-	10	9	-	-	-	1	-	-	-	-	-	-	10	6	5	7	3	3	4	-	-	-
<i>Pleurotaenium</i> sp.	-	-	-	1	10	2	-	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-	-	2
<i>Netrium</i> sp.	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
<i>Pediastrum</i> sp.	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	1	2	-
<i>Spirogyra</i> sp.	24	45	75	65	45	79	158	42	40	54	10	25	89	40	29	54	40	48	75	102	72	90	23	20
<i>Ulothrix</i> sp.	-	-	-	-	50	153	103	75	-	-	-	-	-	-	-	12	8	12	-	-	-	-	-	-
Bacillariophyceae																								
<i>Caloneis</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-
<i>Cymbella</i> sp.	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eunotia</i> sp.	-	-	-	-	-	-	-	-	5	-	8	-	-	-	-	-	-	4	5	-	-	-	-	-
<i>Fragilaria</i> sp.	5	4	18	15	5	12	10	12	-	-	2	-	-	-	12	4	6	8	4	3	-	4	8	-
<i>Navicula</i> sp.	5	4	3	5	7	2	2	3	2	-	5	8	-	-	3	8	2	5	5	2	1	30	27	3
<i>Pinnularia</i> sp.	12	8	20	23	35	30	9	11	12	39	210	5	-	3	2	18	15	19	18	20	14	18	17	4
<i>Synedra</i> sp.	-	1	-	-	-	-	-	-	-	-	1	-	2	2	-	-	-	-	-	-	-	3	6	1
Cyanophyceae																								
<i>Anabena</i> sp.	-	8	19	20	-	-	-	-	-	-	-	-	-	-	2	3	-	2	-	-	-	-	-	-
<i>Lyngbya</i> sp.	-	-	-	-	-	202	252	98	-	3	-	-	-	-	-	-	12	15	4	-	-	-	-	-
<i>Microcystis</i> sp.	-	-	-	-	-	-	-	-	-	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-
<i>Oscillatoria</i> sp.	32	16	-	2	6	3	-	2	18	56	14	-	12	17	35	18	21	28	18	16	3	18	75	12
<i>Phormidium</i> sp.	-	-	-	-	-	24	83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euglenophyceae																								
<i>Euglena</i> sp.	-	2	-	-	-	-	-	-	2	9	4	5	-	-	6	4	2	3	2	-	-	2	-	1
<i>Euglena acus</i>	-	-	-	-	-	-	-	-	1	-	4	2	-	-	-	-	1	2	1	-	-	-	-	3
Dinophyceae																								
<i>Ceratium</i> sp.	-	-	-	-	-	-	-	-	-	-	2	-	5	5	-	-	-	-	-	-	-	-	-	-
<i>Glenodinium</i> sp.	-	-	6	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL PHYTOPLANKTON	92	110	183	187	191	527	630	254	83	166	268	59	110	67	109	139	118	178	166	154	100	173	175	55

TABLE 21: MONTHLY VARIATIONS IN POPULATION ABUNDANCE (n/l) OF PHYTOPLANKTON AT SITE 3 (PADDY-FIELD)

Chlorophyceae	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
<i>Closterium</i> sp.	11	20	-	-	2	3	2	-	8	3	8	18	13	-	-	-	14	4	4	5	-	-	2	10
C. setaceum	-	2	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-	1	-	-	-	-	2	-
<i>Cosmarium</i> sp.	2	5	-	-	3	2	-	3	2	-	4	3	6	2	28	-	-	3	-	-	2	8	2	
<i>Euastrum</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-	-	
<i>Micrastaeris</i> sp.	3	-	-	-	-	-	-	-	1	3	3	2	2	2	2	2	2	3	4	4	8	12	10	
<i>Netrium</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	
<i>Oedogonium</i> sp.	-	-	-	1	-	-	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Pleurotaenium</i> sp.	3	2	-	2	-	-	-	-	-	-	1	4	2	8	3	2	-	2	-	2	1	2	1	
<i>Radiococcus</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	
<i>Scenedesmus quadricaudata</i>	-	10	-	-	-	-	-	-	-	-	25	54	28	18	27	-	3	2	-	-	-	6	-	
<i>Spirogyra</i> sp.	-	-	2	4	-	-	12	3	4	3	4	6	-	3	8	37	15	8	4	5	6	3	3	
<i>Pediastrum</i> sp.	1	4	-	-	3	-	14	11	9	10	9	5	-	2	13	-	-	7	9	10	12	10	3	
<i>Tetraspora</i> sp.	-	-	-	-	-	-	-	-	-	-	-	7	6	-	-	-	-	-	-	-	-	-	-	
<i>Volvox</i> sp.	-	-	-	-	-	5	2	-	-	-	-	-	-	-	-	20	-	3	-	-	-	-	-	
<i>Zygnema</i> sp.	2	-	2	4	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	
Bacillariophyceae																								
<i>Asterionella</i> sp.	8	1	-	-	-	-	-	2	3	20	9	13	5	3	-	-	-	1	-	2	-	-	15	
<i>Caloneis</i> sp.	-	1	-	-	-	-	-	2	1	5	3	-	2	2	2	3	2	3	7	6	8	3	1	
<i>Cymbella</i> sp.	5	1	-	2	-	-	-	2	2	-	2	19	5	2	3	3	2	12	8	6	2	6	12	
<i>Diatoma</i> sp.	2	1	-	-	-	-	-	-	-	1	-	-	-	2	-	2	3	2	2	3	2	4	1	
<i>Eunotia</i> sp.	-	3	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	
<i>Fragilaria</i> sp.	2	-	-	-	3	2	7	15	51	44	12	16	-	-	2	-	-	-	8	10	12	-		
<i>Gyrisigma</i> sp.	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Navicula</i> sp.	45	7	5	13	15	55	34	115	170	80	59	86	39	10	37	32	10	26	35	48	54	52	60	
<i>Pinnularia</i> sp.	20	8	4	2	3	3	12	-	8	11	5	6	16	12	12	25	4	20	8	15	18	16	4	
<i>Stauroneis</i> sp.	3	-	3	-	2	-	-	1	-	-	2	-	-	3	-	7	-	-	2	4	-	-	-	
<i>Synedra</i> sp.	6	4	-	1	-	4	-	5	2	15	4	6	12	3	17	3	6	16	3	2	2	3	3	
Cyanophyceae																								
<i>Microcystis</i> sp.	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Nostoc</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	200	500	400
<i>Oscillatoria</i> sp.	3	-	20	3	-	15	-	3	4	-	13	6	10	-	3	2	-	-	8	10	12	-	12	
<i>Phormidium</i> sp.	-	-	65	6	11	18	19	2	1	-	3	2	-	-	-	-	6	22	-	3	2	1	2	
Chrysophyceae																								
<i>Cryptomonas</i> sp.	-	-	-	-	-	-	-	-	-	-	2	3	1	-	-	-	3	-	-	-	-	-	-	
Euglenophyceae																								
<i>Euglena</i> sp.	1	8	15	3	1	1	9	2	2	2	0	-	-	-	3	-	-	-	-	-	1	2	-	
<i>Euglena acus</i>	-	1	-	-	-	-	-	-	-	-	2	-	-	1	-	-	15	-	-	-	-	-	-	
<i>Phacus</i> sp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2	
Dinophyceae																								
<i>Glenodinium</i> sp.	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	
TOTAL PHYTOPLANKTON	117	79	116	43	43	108	132	166	268	203	140	218	189	82	131	173	125	234	103	125	134	335	613	538

Bacillariophyceae: Percentage composition of different groups of phytoplankton (Fig. 112) indicated that Bacillariophyceae dominated over other groups during most of the months at Site 1 (pond) and comprised between 26.3%-81.7% with highest abundance in July 2000. Further, percentage contribution to the phytoplankton by this group was high from May-September (50.9-69.0%) in first year and between July-September (49.5-75.5%) in the second year at this site. With density ranging between 12-103 n/l (46 ± 25 n/l), it was quantitatively the most important group of phytoplankton in this water body and depicted bimodal pattern of their monthly fluctuations during the study period. It exhibited generally low density from March-June in first year and April-August in the second year with minima in April in first year. The primary maxima was recorded in November in first year and the peak in December in second year of the study. Further, secondary maxima was seen in July (76 n/l) and February (51 n/l) during the first and the second year respectively. Amongst its members *Navicula* sp. was predominantly seen (2-55 n/l) and this species along with *Fragilaria* sp. was mainly responsible for the summer maxima of phytoplankton during both the years in the pond. *Diatoma* sp. was least abundant (1-2 n/l) and occurred only in September, October and December 2000. Among other members of the group, *Cymbella* sp. showed unimodal pattern of monthly fluctuation in their density with maxima in November and October in the two years respectively.

At Site 2 (peat bog), Bacillariophyceae was equally important as it contributed 1.8-84.3% of density of phytoplankton. Its population density ranged between 2-226 n/l (36 ± 43 n/l) during the study period with relatively narrow range and low mean during the second year between 2-58 n/l (26 ± 18 n/l). Low density was generally seen from February-October during both the years except during the early monsoon when secondary maxima were registered. Its density depicted unimodal pattern of monthly fluctuation with first maxima in December and secondary in June and July during the two years of study respectively and minima in February in second year. Amongst members of this group *Pinnularia* sp. showed a higher winter maxima (210 n/l) and a relatively smaller summer maxima (20 n/l) in June in first year and September in second year respectively. However this species was relatively more predominant during the study period (0-210 n/l) except between February-April 2001 in this peat bog. *Fragilaria* sp. (0-18 n/l) was more abundant in summer while *Navicula* sp. (0-30 n/l) was more abundant in winter. *Caloneis* sp. (0-2 n/l) was the least abundant and was recorded only in July and August of second year.

At Site 3, Bacillariophyceae was quantitatively predominant (Fig. 112) during most of the study period and comprised between 10.3-88.4% of phytoplankton density. It ranged between 12-237 n/l (83 ± 53 n/l) with low density between April-August exhibiting minima in April and maxima in October 2000. This group depicted a broadly bimodal pattern of their monthly abundance with peak in October and second maxima in January (146 n/l). *Navicula* sp. is quantitatively important as its density ranged between 5-170 n/l remaining most abundant during the paddy season in both the years. However, it ranged less widely during the second year (10-60 n/l). *Fragilaria* sp. (0-51 n/l) and *Asterionella* sp. (0-20 n/l) were other species of quantitative importance and depicted their maxima in late paddy growing period especially in first year.

Cyanophyceae: Cyanophyceae was an important group in the pond as it contributed 0.0-71.3% of phytoplankton density dominating all other groups quantitatively between November-December in first year and between October-January in the second year of study. Their population density ranged between 0-184 n/l (38 ± 56 n/l) in this ecosystem (Site 1). While the peak density was registered in the month of December 2000, this group was not represented during May and August of the first year and May and June of the second year. Further, very low density was seen between February-August (0-10 n/l), thereby, depicting a unimodal pattern of monthly variations in its population density. Amongst members of this group, *Microcystis* sp. was least abundant (0-6 n/l) followed by *Phormidium* sp. (0-10 n/l). However, major contributor to abundance of the blue-green algae in the pond was *Oscillatoria* sp. (0-180 n/l) with maximum abundance during December 2000. It was recorded more abundantly between September-December in first year and between September- January in the second year.

At Site 2, Cyanophyceae comprised between 2-335 n/l (49 ± 77 n/l) during the study period with the highest density in August 2000 and the least in the month of January 2001. The range and mean values of its density differed between first and second year of study with a wider range of 2-335 n/l (72 ± 104 n/l) in first year and significantly narrow range of 3-75 n/l (26 ± 19 n/l) during the second year. This group registered higher summer maxima and slightly lower secondary winter maxima (75 n/l) in second year and contributed significantly to total phytoplankton density along with Chlorophyceae in this peat bog. Percentage contribution to total phytoplankton density ranged between 3.0-53.2%

dominating the other groups in terms of percentage composition during the month of August 2000. Quantitatively important species in this group are *Lyngbya* sp. and *Oscillatoria* sp. of which the former was found at its peak abundance from July-September during the study period and the later in November with significant density almost throughout the year.

At Site 3 (paddy-field), Cyanophyceae comprised between 0-500 n/l (58 ± 131 n/l) with peak density in December in second year and maxima in April during the first year. The group comprised between 0.00-81.57% and was not recorded in March during the second year of study in this ecosystem. Quantitatively important species in this group are *Nostoc* sp. (0-500 n/l), which depicted a bloom during November-January in the second year of study only. *Oscillatoria* sp. (0-20 n/l) and *Phormidium* sp. (0-65 n/l) were more abundant during pre-paddy and during paddy seasons but were less abundant in winters during the study period.

Euglenophyceae, another group of phytoplankton, was represented by low density at Site 1 (pond) and Site 2 (peat bog) i.e., between 0-4 n/l (1 ± 1 n/l) and 0-9 n/l (1 ± 1 n/l) respectively and between 0-15 n/l (3 ± 5 n/l) at Site 3 (paddy-field). While at Site 1, it was represented by a single *Euglena* sp. (0-4 n/l), at Site 2 it comprised of *Euglena* sp. (0-6 n/l) and *E. acus* (0-4 n/l). At Site 3, Euglenophyceae was represented by *Euglena* sp. (0-15 n/l), *E. acus* (0-15 n/l) and *Phacus* sp. (0-2 n/l).

Dinophyceae was represented by two species viz. *Caratium* sp. (0-5 n/l) which occurred at Site 2 during December in first year and February-March in second year and *Glenodinium* sp. (0-6 n/l) which was recorded at Site 2 between April-May during the first year and at Site 3 during November in first year. Chrysophyceae was represented by *Cryptomonas* sp. occurring only at Site 3 during December 2000-February 2001 with low density of 0-3 n/l.

Zooplankton: Zooplankton abundance fluctuated with very wide range and high mean at Site 1 (pond) i.e., between 33-1071 n/l (180 ± 243 n/l) and exhibited Copepoda > Cladocera > Rotifera > Rhizopoda > Nematoda > Ostracoda = Gastrotricha. At Site 2 (peat bog) and Site 3 (paddy-field), comparatively narrow range and low mean values were recorded between 34-123 n/l (66 ± 20 n/l) and 32-140 n/l (68 ± 27 n/l) respectively. Further at Site 2, zooplankton registered Cladocera > Rotifera > Copepoda = Rhizopoda > Ostracoda =

Nematoda. On the other hand at Site 3 (paddy-field), zooplankton depicted the following spectrum i.e., Rotifera > Cladocera > Copepoda > Rhizopoda > Ostracoda = Nematoda = Gastrotricha. Maximum density of zooplankton was recorded at Site 1 during April and minimum at Site 3 during May in the first year of study. Further, zooplankton density remained relatively higher during pre-monsoon period particularly between March-May at all sites and low from August-November during the study period. At Site 1, wide variations were observed between two annual ranges and mean values. During the first year, it ranged more widely between 33-1071 n/l (234 ± 328 n/l) and during the second year between 43-282 n/l (127 ± 98 n/l). Further, it exhibited unimodal pattern in their monthly fluctuations during the study period with a distinct peak in April during the first year and a relatively smaller primary maxima during March in the second year (Fig. 109). However at Site 2, the density remained almost uniformly low in the first year and exhibited a narrow range between 34-79 n/l (60 ± 14 n/l). In addition, it exhibited a wider range and higher mean between 40-123 n/l (72 ± 23 n/l) during the second year of the study depicting a unimodal pattern of their monthly variations. Peak density was recorded during March and minima in January 2001. At Site 3 (paddy-field), annual mean and ranges differed marginally between the two years exhibiting a relatively wider mean during the second year between 42-140 n/l (76 ± 32 n/l) and a narrow range in first year between 32-95 n/l (59 ± 17 n/l). It depicted a broadly bimodal pattern of monthly fluctuation with primary maxima in August and secondary in April (73 n/l) in first year and July and April (139 n/l) in second year respectively.

Zooplankton comprised an important component of net plankton at Site 1 and contributed up to 14.5-96.1% ($51.9 \pm 27.3\%$) with maximum percentage of zooplankton registered during April in first year. However, at Site 2 and 3, it varied between, 10.4-64.7% ($31.5 \pm 12.0\%$) and 7.54-51.5 % ($32.0 \pm 12.2\%$) respectively with minimum at Site 3 during May in the first year. Further at Site 1, zooplankton density was greater than that of phytoplankton during February-June ranging between 61.7-96.1% ($79.8 \pm 15.6\%$) in the first year. In the second year of study it dominated over phytoplankton during January-August with 52.6-88.1 ($69.5 \pm 13.8\%$). At Site 3, zooplankton was dominant quantitatively only during April (51.5%) in the second year.

Species diversity of zooplankton (Tables: 16-18) at three sites computed *vide* Shannon's index (H') ranged between 0.930 - 3.232 (2.306 ± 0.82), 1.871-3.240 ($2.745 \pm$

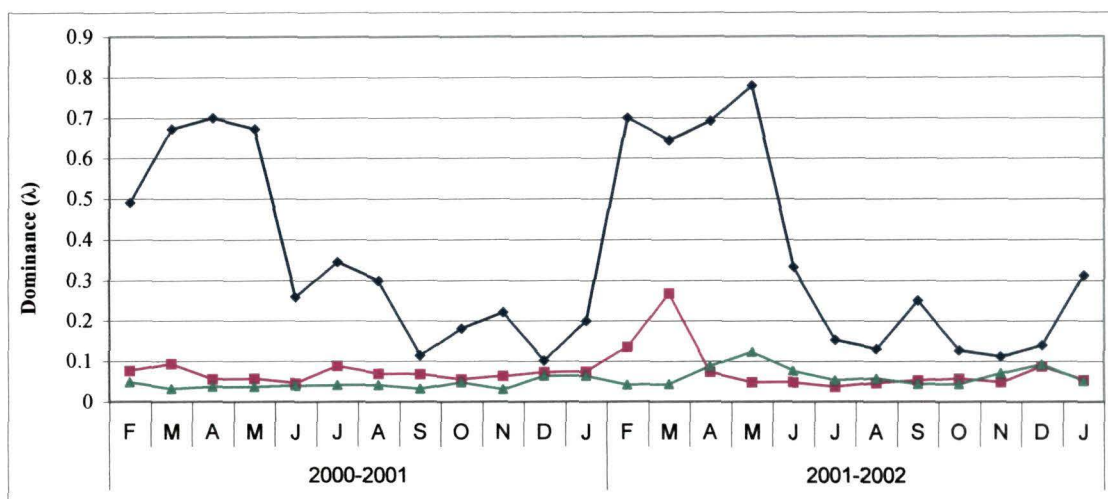
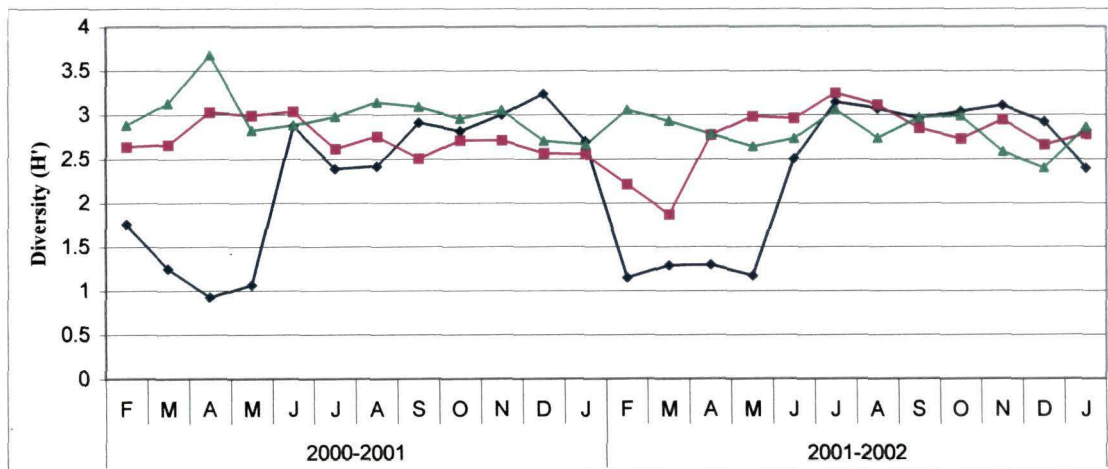


FIG. 116: MONTHLY VARIATIONS OF SPECIES DIVERSITY, DOMINANCE AND EVENNESS OF ZOOPLANKTON

0.29), 2.397-3.676 (2.904 ± 0.25) respectively and the same by Menhinicks's index ranged between 0.458-2.860 (1.843 ± 0.79), 1.172-3.255 (2.474 ± 0.43) and 1.768-3.467 (2.647 ± 0.51) respectively with two indices values broadly corresponding with each other in different months. Species diversity of zooplankton depicted significantly higher range at Site 1 (pond) but the mean diversity was highest at Site 3 (paddy-field). Maximum diversity was depicted at Site 1 in December in the first year as indicated by Shannon's index and in August of the same year *vide* Menhinick's index. The minimum diversity was also seen at Site 1 during April in the first year. Further at this site, broadly identical ranges and mean values were registered during two annual observations depicting broadly unimodal pattern of their fluctuations during the study period (Fig. 116). The diversity was particularly higher from June-December and low from March-May in this water body. At Site 2 (peat bog), Shannon's recorded maximum diversity in July 2001 and Menhinick's in April 2000. However the minimum diversity was recorded in March 2001 by both the indices. Further in this ecosystem, the diversity of zooplankton during the different months ranged more narrowly in the first year of study between 2.508-3.040 (2.732 ± 0.19) and more widely in second year between 1.871-3.240 (2.758 ± 0.38) *vide* Shannon's index and also with similar pattern depicted by Menhinick's. The diversity in the monthly zooplankton community fluctuated with a multimodal pattern remaining closer to mean during the first year and exhibited several maxima in the second year. Peak and minima were recorded in July and March respectively in the second year. Similarly, species diversity of zooplankton in the paddy-field (Site 3) broadly registered identical ranges and mean values during study period and followed multimodal pattern of their fluctuations in both the years. The peak species diversity was recorded during April in first year and remained consistently high during the study period in this ecosystem.

Dominance of zooplankton at three sites ranged between 0.102-0.779 (0.360 ± 0.24), 0.037-0.267 (0.074 ± 0.05), 0.030-0.122 (0.054 ± 0.02) *vide* Simpson's index (λ) and between 0.184-0.815 (0.450 ± 0.23), 0.108-0.488 (0.185 ± 0.08) 0.077-0.329 (0.140 ± 0.06) *vide* Berger-Parker's index (d) respectively during the study period. Species dominance at Site 1 (pond) was predominantly higher than other two sites with maximum dominance observed in May during second year which is also confirmed *vide* Berger-Parker's index, while minimum value was recorded at Site 3 (0.103) during November in the first year.

Further at Site 1, a broadly trimodal pattern in the first year was observed with higher maxima during April-May in both the years. Peak was recorded during May in second year and declined during the monsoon till December with minima in December of the first year. At Site 2 (peat bog), low dominance by zooplankton was indicated during the study period which ranged between 0.046-0.094 (0.069 ± 0.01) in first year and relatively more widely between 0.037-0.267 (0.079 ± 0.07) in second year with minima in July and maxima in March. Relatively higher dominance was computed after monsoon till beginning of summer in following year. Species dominance of zooplankton in the paddy-field was least among the study sites which ranged between 0.077-0.143 (0.112 ± 0.02) in first year and between 0.107-0.33 (0.167 ± 0.07) in the second year *vide* Berger-Parker's index and between 0.030-0.06 (0.043 ± 0.11) in first year and 0.042-0.122 (0.065 ± 0.03) in the second year *vide* Simpson's index. Even though irregular monthly fluctuations were observed in this ecosystem (Fig. 116), generally higher values were observed in pre-paddy season in the second year and lower value during paddy seasons of both the years depicting peak in May in the second year and minima in November in the first year.

Evenness computed (E_1) ranged between 0.343-1.134 (0.823 ± 0.28), 0.729-0.967 (0.925 ± 0.05) and 0.853-1.142 (0.959 ± 0.05) at three sites respectively with broadly identical mean values. Maximum evenness among three sites was recorded at Site 3 (paddy-field) in April and minimum at Site 1 (pond) also in April in the first year of the study. Monthly evenness values fluctuated most widely at Site 1, broadly depicting a unimodal pattern. There was a gradual decline from February-May during both the years and minima was recorded in May during the first year of the study. Evenness of zooplankton increased during monsoon in this ecosystem and depicted peak in September in the first year and primary maxima in November during the second year of study. There were no notable variations in evenness at Site 2 with values remaining close to mean throughout the study period. Peak evenness in this water body was recorded in September (0.967) and minima in March (0.729) during the second year. At Site 3, E_1 ranged between 0.950-1.142 (0.983 ± 0.05) in first year and between 0.853-0.99 (0.934 ± 0.04) in the second year with broadly unimodal pattern of fluctuation during both the years. Highest evenness was recorded in April in first year and primary maxima in August and minima in May during second year of the study.

Rotifera: Monthly abundance of this phylum ranged between 6-21 n/l (11 ± 4 n/l), 5-30 n/l (15 ± 6 n/l) and 9-58 n/l (21 ± 13 n/l) at Sites 1-3 respectively and occurred most abundantly at Site 3 (paddy-field). Further Rotifera comprised between 0.8-30.6% ($14.6 \pm 9.4\%$), 6.5-43.9% ($23.4 \pm 7.6\%$) and 12.7-56.8% ($30.9 \pm 11.2\%$) of zooplankton abundance at these sites respectively being most prominent group quantitatively at Site 3. Maximum and minimum rotifer percentage compositions were registered at Site 3 and at Site 1 during August and April respectively in the first year. Monthly variations of rotifer density at Site 1 and 2 (pond and the peat bog respectively) fluctuated with bimodal pattern and at Site 3 (paddy-field) with broadly unimodal pattern (Fig. 118). Further at Site 1, the rotifer density was low between September-November (6-8 n/l) with minima depicted in November in first year but in May (6 n/l) in the second year. Peak was depicted in June in the first year and primary maxima was recorded in July in the second year of the study. Secondary maxima of the first and the second year were seen in Dec (15 n/l) and March (14 n/l) respectively. At Site 2, the density of rotifers ranged less widely between 7-22 n/l (14 ± 4 n/l) during the first year and between 5-30 n/l (17 ± 7 n/l) during the second year. Minima and maxima were recorded in February and June 2001 respectively. At Site 3, maxima (54 n/l) was recorded in August in first year and peak in July (58 n/l) during the second year of study. Further, minima was recorded in December during the second year of the study. It was found to be in greater abundance during paddy season especially in the early part of it (June-July).

Among the reported species of Phylum Rotifera, *Euchlanis dilatata* was relatively more important species in quantitative terms at all the sites and ranged between 0-7 n/l, 0-4 n/l and 0-11 n/l at Sites 1-3 respectively registering higher density during the warmer months. Similarly *Testudinella patina* at Site 1 (0-7 n/l) was seen in its peak density in January (second year) and was generally more abundant in pre-monsoon. At Site 2 (peat bog), *Colurella obtusa* (0-6 n/l) and *Philodina* sp. (0-6 n/l) showed their maxima in September in the first year and October and July respectively in the second year depicting their higher abundance during the monsoon in this water body. Further at this site, *Anuraeopsis fissa* was recorded in significant density (4-17 n/l) only during November-January in the second year of study. Similarly, *Brachionus quadridentatus* at Site 3 (paddy-field) was found in high abundance only during two months of the study from June-July (5-11 n/l) in the second year. At this site *Epiphanes* sp. (0-13 n/l) depicted its peak density in

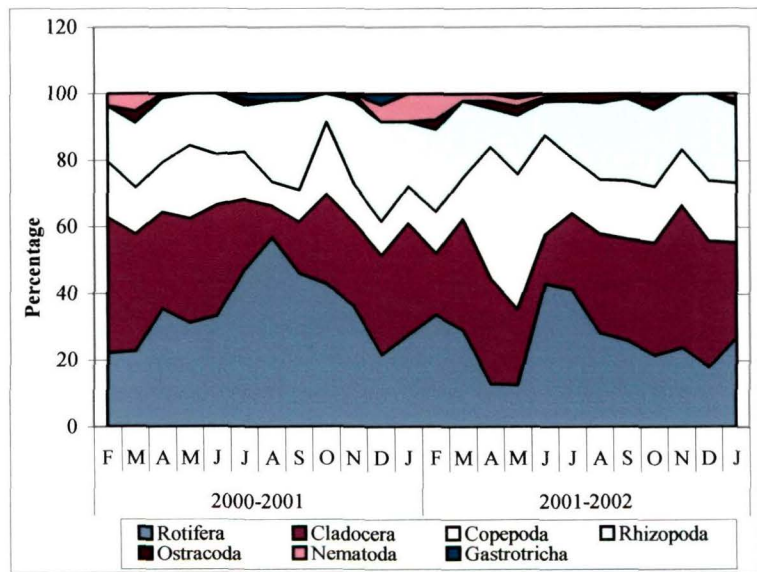
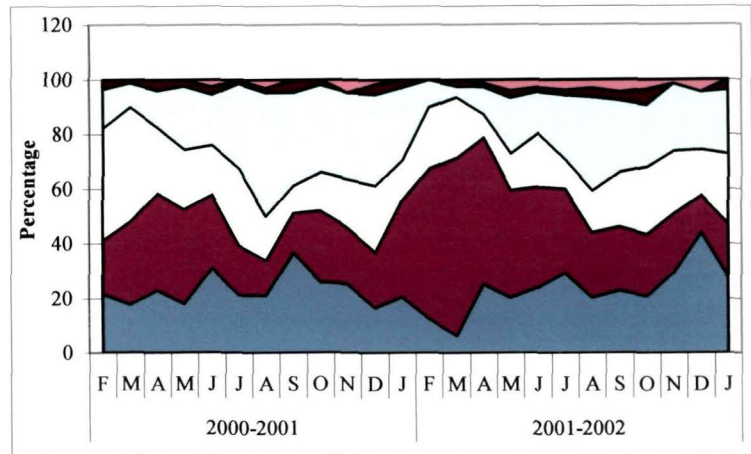
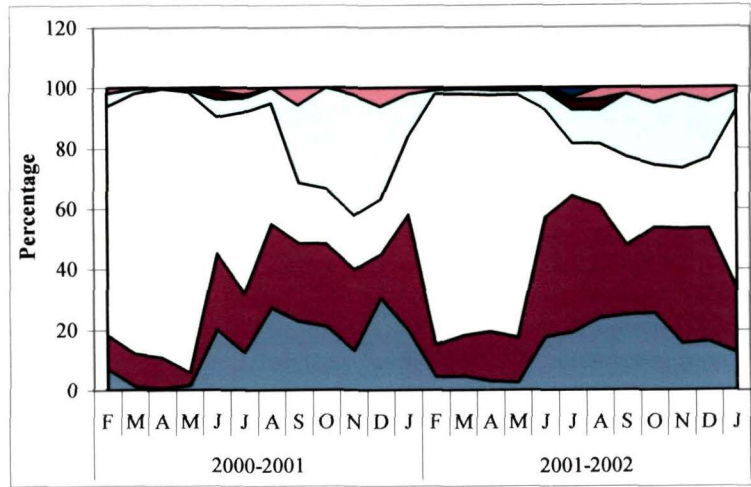


FIG. 117: MONTHLY VARIATIONS IN PERCENTAGE COMPOSITION IN DIFFERENT GROUPS OF ZOOPLANKTON

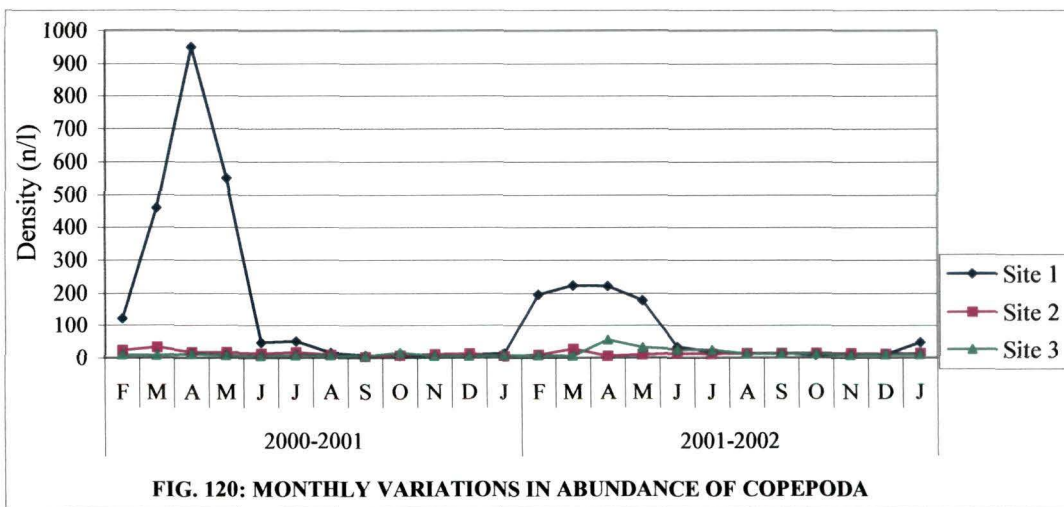
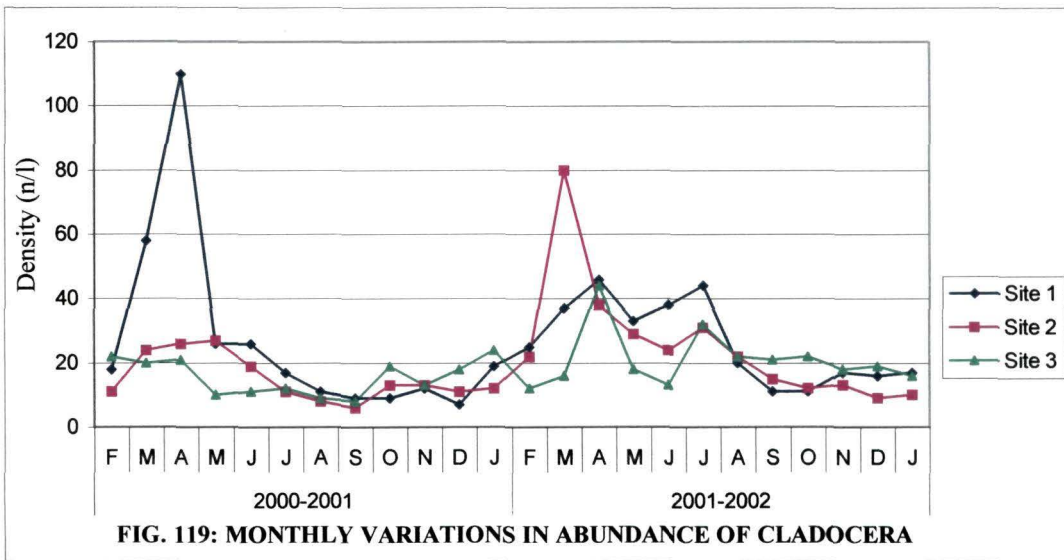
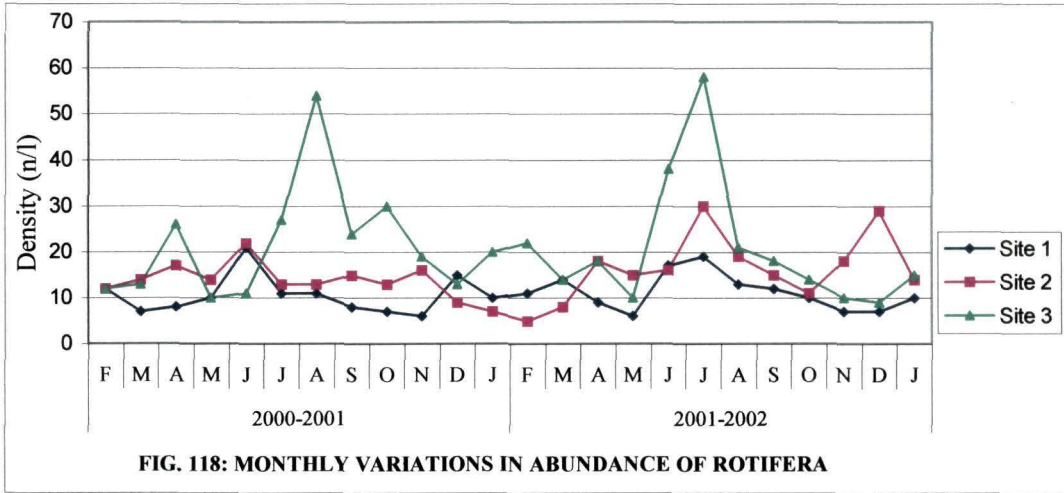


TABLE 22: MONTHLY VARIATIONS IN ABUNDANCE (n/l) OF ZOOPLANKTON AT SITE 1 (POND)

Rhizopoda	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
<i>Arcella</i> sp.	2	3	2	2	2	1	-	3	2	10	-	1	-	3	1	2	-	-	-	2	1	-	-	-
<i>A. discoides</i>	1	1	-	-	-	-	-	-	2	3	2	-	2	-	-	-	2	-	-	1	3	3	-	-
<i>A. megastoma</i>	-	-	-	-	-	-	-	4	-	1	3	-	-	-	-	-	-	-	1	-	-	-	-	-
<i>Centropyxis aculeata</i>	-	-	-	1	1	-	-	-	2	1	4	3	-	-	-	-	2	2	1	2	3	2	3	2
<i>C. ecornis</i>	-	-	-	1	2	1	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-
<i>Diffugia</i> sp.	-	2	-	-	1	2	-	2	1	2	1	1	-	-	2	1	3	2	3	3	2	4	2	1
<i>Euglypha</i> sp.	4	2	1	-	-	-	2	-	4	1	5	2	1	2	2	-	-	3	1	3	1	2	-	2
Rotifera																								
<i>Brachionus quadridentatus</i>	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
<i>Cephalodella</i> sp.	1	-	1	1	-	-	-	-	1	-	1	-	3	4	-	-	-	-	-	1	-	-	-	-
<i>Colurella uncinata</i>	-	-	-	-	-	-	-	1	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-
<i>Conochilus</i> sp.	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Epiphanes</i> sp.	-	1	-	1	3	2	-	-	-	-	2	-	-	-	-	-	2	1	1	2	-	-	-	-
<i>Euchlanis dilatata</i>	3	2	2	2	1	1	1	-	-	1	-	-	-	-	3	4	5	7	4	3	4	2	3	4
<i>Lecane aculeata</i>	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. hornemanni</i>	2	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2
<i>L. inermis</i>	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. luna</i>	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
<i>L. lunaris</i>	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
<i>Lepadella ovalis</i>	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>L. patella</i>	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	-
<i>Macrochaetus sericus</i>	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Monommata longiseta</i>	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
<i>Mytilina ventralis</i>	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
<i>Philodina</i> sp.	1	1	-	-	1	2	3	3	-	-	2	-	-	-	-	-	2	1	1	2	-	-	-	-
<i>Platyas polyacanthus</i>	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	1	-
<i>P. quadricornis</i>	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-
<i>Scaridium longicaudum</i>	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-
<i>Testudinella patina</i>	2	3	2	2	5	-	-	-	3	2	2	7	5	3	3	2	3	4	1	2	3	1	-	2
<i>Trichocerca pusilla</i>	2	-	2	3	1	3	2	2	3	1	2	-	2	3	1	-	-	-	2	2	2	2	1	-

Table 22 contd..

	2000-2001												2001-2002											
Cladocera	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
<i>Ceriodaphnia cornuta</i>	2	5	3	4	4	-	-	-	2	-	2	2	22	32	29	7	5	2	-	-	-	-	-	8
<i>C. reticulata</i>	12	45	99	3	3	-	-	-	-	1	3	10	-	-	3	4	7	8	4	3	1	4	6	2
<i>Simocephalus serrulatus</i>	3	3	-	-	1	2	-	-	-	-	-	3	-	-	5	8	7	9	3	-	-	-	-	
<i>S. vetulus</i>	-	-	3	3	1	1	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	
<i>Scapholeberis kingi</i>	-	1	2	5	5	-	-	-	-	-	-	-	-	-	8	2	-	-	-	-	-	-	-	
<i>Moina micrura</i>	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	1	2	3	2	-	-	-	-	
<i>Macrothrix laticornis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	-	-	-	-	
<i>Pleuroxus similis</i>	-	-	-	3	2	1	4	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	
<i>C. barroisi</i>	-	-	-	1	2	-	1	1	2	-	-	-	-	-	-	-	-	-	2	1	3	-	-	
<i>Chydorous sphaericus</i>	-	1	-	-	3	3	2	4	3	4	1	-	-	-	-	3	16	15	6	4	3	1	2	
<i>Alona affinis</i>	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	3	1	
<i>A. costata</i>	-	-	1	1	-	1	-	-	2	2	1	-	-	-	-	1	2	-	-	2	2	3	2	
<i>A. guttata</i>	-	1	-	2	2	3	-	2	-	4	-	-	-	-	-	1	-	2	-	-	2	3	2	
<i>A. intermedia</i>	1	2	-	-	-	-	-	-	-	-	-	2	3	5	-	-	-	-	-	-	-	-	2	
<i>A. monocantha</i>	-	-	-	1	-	2	4	2	-	1	-	-	-	-	-	1	-	-	1	1	-	4	5	
<i>Alona rectangula</i>	-	-	-	3	2	3	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	
Copepoda																								
<i>Tropocyclops</i> sp.	80	360	750	400	27	30	12	4	6	5	5	6	165	180	195	173	32	12	7	12	5	5	6	25
<i>Eucyclops</i> sp.	8	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4
Nauplius larva	35	80	200	150	20	22	4	3	0	3	4	7	30	43	25	5	2	5	4	2	3	4	2	18
Ostracoda																								
<i>Cypris</i> sp.	-	-	-	3	3	1	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-	-	-	
Nematoda	3	2	-	2	1	2	-	2	-	1	3	1	2	1	2	2	1	1	2	1	2	1	2	1
Gastrotricha																								
<i>Chaetonotus</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	
TOTAL ZOOPLANKTON	163	535	1071	595	104	87	40	35	33	45	49	50	236	280	282	222	96	98	54	48	39	45	43	80

TABLE 23: MONTHLY VARIATIONS IN ABUNDANCE (n/l) OF ZOOPLANKTON AT SITE 2 (PEAT BOG)

	2000-2001												2001-2002												
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	
Rhizopoda																									
<i>Actinosphaerium</i> sp.	-	-	3	3	1	-	-	-	-	-	-	2	-	-	1	2	-	-	-	-	-	-	1	-	
<i>Arcella discooides</i>	3	-	-	-	-	-	2	3	4	5	2	-	2	3	-	-	-	2	3	3	3	4	2	-	
<i>A. megastoma</i>	-	-	-	-	-	-	3	2	2	2	-	1	-	-	-	-	-	4	2	3	1	1	-	-	
<i>Centropyxis aculeata</i>	2	-	-	2	3	2	3	2	2	1	4	2	1	-	3	3	4	2	3	1	1	-	4	1	
<i>C. ecornis</i>	-	-	1	1	-	1	1	-	-	-	-	2	-	-	-	-	1	2	-	-	-	1	1	4	
<i>Diffugia</i> sp.	2	4	2	4	3	6	6	4	5	9	8	2	1	2	2	5	2	4	7	6	4	6	4	3	
<i>D. lebes</i>	1	2	2	6	4	9	12	-	-	-	-	-	-	-	-	3	2	8	13	2	-	-	-	1	
<i>Euglypha</i> sp.	-	1	2	2	2	1	1	3	3	3	4	-	-	-	1	2	1	2	4	2	3	3	2	3	
Rotifera																									
<i>Anuraeopsis fissa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	17	5	
<i>Conochilus</i> sp.	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Colurella obtusa</i>	-	2	1	2	-	1	2	6	2	1	1	-	-	-	2	3	2	4	3	4	5	2	-	1	
<i>Dicranophorous</i> sp.	-	-	2	1	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	
<i>Epiphanes</i> sp.	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Euchlanis dilatata</i>	3	4	1	2	2	-	-	-	-	-	-	2	2	2	3	-	-	2	-	-	-	-	-	3	
<i>Lecane aculeata</i>	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	2	2	-	-	-	-	-	
<i>L. bulla</i>	2	3	1	1	-	-	-	1	-	-	-	-	-	2	4	2	-	-	-	-	-	2	-	-	
<i>L. closteroerca</i>	3	1	1	1	2	2	2	-	-	-	-	2	-	2	2	3	3	5	3	2	1	3	2	1	
<i>L. doryssa</i>	-	-	2	3	4	3	-	-	-	5	-	-	-	-	-	1	4	3	3	-	-	1	2	-	
<i>L. hamata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3	2	-	-	-	-	-	
<i>L. inermis</i>	1	-	-	-	2	-	-	-	-	-	1	1	-	-	2	1	-	-	-	-	-	-	-	-	
<i>L. luna</i>	-	-	-	-	-	-	2	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>L. lunaris</i>	2	-	4	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	2	3	2	
<i>Lepadella ovalis</i>	-	-	-	-	-	-	-	-	3	3	-	1	-	-	-	-	-	-	2	-	-	-	-	-	
<i>L. patella</i>	-	2	1	2	-	-	-	-	-	-	-	-	-	-	1	2	3	2	1	-	-	-	-	-	
<i>Macrochateus sericus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	1	2	1	
<i>Monommata longiseta</i>	-	-	-	-	-	-	1	-	-	-	-	-	2	1	-	-	1	2	1	-	-	-	-	-	
<i>Philodina</i> sp.	1	1	1	1	3	3	3	6	5	3	3	-	-	-	-	1	1	2	4	2	4	3	1	-	1
<i>Trichocerca cylindrica</i>	-	1	1	-	1	-	-	2	1	-	-	-	-	-	2	-	-	-	-	3	2	2	-	-	
<i>T. longiseta</i>	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>T. pusilla</i>	-	-	1	1	2	3	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	3	-	
<i>Trichotria tetractis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	

Table 23 contd...

Cladocera	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
<i>Diphanosoma excisa</i>	-	-	2	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	
<i>Daphniopsis</i> sp.	-	8	4	2	1	-	-	-	-	-	-	-	13	60	12	8	-	-	-	-	-	-	-	
<i>Ceriodaphnia cornuta</i>	-	1	4	1	-	-	-	-	-	-	-	-	-	-	2	-	3	2	2	-	-	-	-	
<i>Simocephalus serrulatus</i>	2	2	2	7	3	2	4	2	3	-	6	8	5	12	6	5	4	4	2	3	2	4	3	6
<i>Moina micrura</i>	-	-	1	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	
<i>Pleuroxus similis</i>	-	3	1	1	4	2	2	-	-	-	-	-	-	-	1	-	3	2	4	3	1	-	-	
<i>Chydorous sphaericus</i>	2	2	1	1	-	-	-	-	2	2	-	-	-	-	-	3	4	7	4	5	4	2	-	1
<i>Alona costata</i>	3	2	-	2	1	-	-	-	3	4	2	-	-	8	5	4	2	-	2	1	3	4	2	1
<i>A. guttata</i>	4	6	11	10	6	4	2	3	3	3	-	-	-	-	12	9	8	11	6	3	2	2	4	-
<i>A. monocantha</i>	-	-	-	2	2	-	-	-	2	4	3	2	-	-	-	-	-	-	-	-	-	-	-	2
<i>A. rectangula</i>	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
<i>Macrothrix laticornis</i>	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-	1	-	-
<i>Biapertura karua</i>	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copepoda																								
<i>Tropocyclops</i> sp.	7	20	11	12	10	14	8	4	7	9	8	4	5	9	4	3	8	6	8	10	8	4	5	6
<i>Eucyclops</i> sp.	4	2	4	2	1	1	-	-	-	-	-	-	-	-	-	3	2	3	2	-	-	2	3	2
<i>Diaptomus</i> sp.	-	3	-	-	-	-	-	-	-	-	-	-	2	14	-	-	-	-	-	-	-	-	-	-
Nauplius larva	12	8	3	3	2	2	2	-	-	2	5	1	2	4	2	4	3	2	4	3	5	8	3	5
Ostracoda																								
<i>Cypris</i> sp.	2	1	3	2	2	1	1	2	1	-	2	1	-	3	1	2	1	2	3	2	3	-	-	2
Nematoda																								
	-	-	-	-	2	-	2	-	-	3	1	-	-	1	1	3	2	4	3	3	2	1	3	-
TOTAL ZOOPLANKTON	56	79	74	78	71	61	62	41	50	63	54	34	40	123	71	74	66	102	93	65	53	61	66	51

TABLE 24: MONTHLY VARIATIONS IN ABUNDANCE (n/l) OF ZOOPLANKTON AT SITE 3 (PADDY FIELD)

Rhizopoda	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
<i>Actinosphaerium</i> sp.	-	-	-	-	-	1	3	1	-	2	1	-	1	1	-	-	-	-	-	-	-	-	-	-
<i>A. discoides</i>	2	3	4	2	2	1	3	3	2	3	-	2	1	2	3	3	4	3	3	4	3	2	5	1
<i>Arcella megastoma</i>	3	1	3	2	1	1	5	4	1	3	-	6	1	-	-	3	2	11	5	5	3	1	2	4
<i>Cetropyxis aculeata</i>	1	-	5	1	1	4	3	2	2	-	7	-	3	1	6	4	2	7	4	2	2	3	4	3
<i>C. ecornis</i>	-	1	-	-	-	-	-	-	-	-	-	-	2	3	-	2	-	-	-	-	-	-	-	-
<i>Diffugia</i> sp.	1	3	-	-	2	1	4	2	-	1	3	6	4	1	4	-	-	3	5	4	2	-	1	2
<i>D. lebes</i>	-	1	2	-	1	-	5	2	1	-	-	-	-	-	-	-	1	-	-	2	3	-	-	-
<i>Euglypha</i> sp.	2	2	-	-	-	-	-	-	-	4	7	-	4	3	3	2	-	-	-	-	2	1	1	3
Rotifera																								
<i>Brachionus angularis</i>	-	-	-	1	-	-	2	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-
<i>B. quadridentatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	5	-	-	-	-	-	-
<i>Cephalodella</i> sp.	1	1	1	-	1	-	3	2	2	1	-	-	1	-	2	-	-	-	-	2	1	-	-	-
<i>Colurella obtusa</i>	-	1	2	-	1	5	3	1	5	1	-	-	-	2	-	-	-	3	-	2	2	-	-	-
<i>C. uncinata</i>	-	-	-	-	-	5	4	3	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
<i>Epiphanes</i> sp.	-	1	1	1	3	-	1	-	4	2	-	-	-	-	2	-	2	13	6	5	2	-	-	-
<i>Euchlanis dilatata</i>	4	2	4	2	2	2	11	1	-	3	3	2	1	1	4	2	4	4	7	3	4	5	4	3
<i>Lecane aculeata</i>	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
<i>L. bulla</i>	2	1	2	1	2	3	9	4	2	2	1	3	8	2	2	3	-	6	4	3	1	1	-	4
<i>L. closteroerca</i>	1	2	4	-	-	-	2	1	2	-	-	-	-	-	3	-	-	4	2	-	-	1	-	1
<i>L. hamata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	2	-	-	-	-	-	-
<i>L. luna</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-
<i>L. lunaris</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	2	2	2	-	-	-	-	-
<i>L. papuana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	2	-	-	-	-	-	-
<i>L. quadridentatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
<i>Lepadella acuminata</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
<i>L. ovalis</i>	2	-	3	2	-	5	3	1	-	-	2	2	2	3	-	-	-	2	-	-	-	-	-	1
<i>L. patella</i>	2	3	3	-	1	3	6	3	4	1	2	6	2	1	2	-	-	-	-	2	2	2	4	5
<i>Platyias patulus</i>	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	5	7	-	-	-	-	-	-
<i>P. quadricornis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
<i>Philodina</i> sp.	-	1	1	2	-	-	3	2	4	1	-	-	-	-	-	-	-	-	-	2	-	1	1	-
<i>Scaridium longicaudum</i>	-	-	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Testudinella patina</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-
<i>Trichocerca cylindrica</i>	-	-	2	-	-	-	4	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>T. longiseta</i>	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>T. pusilla</i>	-	-	1	1	1	1	2	2	2	4	3	3	2	1	-	-	-	6	-	1	-	-	-	2
<i>T. rattus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
<i>Trichotria tetractis</i>	-	-	-	-	-	-	-	-	-	4	2	4	2	-	-	1	-	-	-	-	-	-	-	-

Table 24 contd...

	2000-2001												2001-2002											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
Cladocera																								
<i>Ceriodaphnia reticulata</i>	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Scapholeberis kingi</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
<i>Moina micrura</i>	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
<i>Macrothrix laticornis</i>	-	-	-	1	4	-	-	-	-	1	-	-	-	-	4	2	-	4	3	2	-	-	-	-
<i>Pleuroxus similis</i>	8	4	5	1	3	2	-	1	4	2	7	8	5	7	9	4	4	-	3	4	4	8	11	5
<i>C. barroisi</i>	-	-	2	-	-	3	2	2	3	2	-	-	-	-	-	-	-	-	3	2	1	-	-	
<i>Chydorus sphaericus</i>	3	2	5	1	2	4	2	-	2	1	-	-	-	-	2	-	-	17	7	4	8	4	2	-
<i>Alona costata</i>	3	5	3	2	1	2	3	1	5	3	6	9	3	1	9	2	6	3	4	3	4	3	4	6
<i>A. guttata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	1	-	-	-	-	-	-	-
<i>A. intermedia</i>	3	4	-	3	-	1	-	1	-	1	5	5	2	3	6	2	-	-	-	2	-	-	3	
<i>A. monacantha</i>	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-
<i>A. rectangularis</i>	3	2	4	-	-	-	2	3	3	2	-	-	1	-	2	2	-	3	-	1	2	1	2	2
<i>Biaprtura karua</i>	2	3	2	1	1	-	-	-	2	-	-	-	1	3	10	3	2	3	5	4	-	1	-	-
Copepoda																								
<i>Tropocyclops</i> sp.	3	4	7	3	3	3	3	5	10	3	4	4	5	3	32	26	16	12	9	4	5	3	7	6
<i>Allodiaptomus</i> sp.	1	2	2	-	-	-	-	-	-	-	-	-	-	3	5	-	-	-	-	-	-	-	-	1
Nauplius larva	5	2	2	4	2	5	4	-	5	2	3	4	3	0	18	6	10	11	3	8	6	4	2	3
Ostracoda																								
<i>Cypris</i> sp.	-	2	1	-	-	1	-	-	-	1	-	-	2	-	3	2	1	3	2	1	2	-	-	1
Nematoda																								
	2	3	-	-	-	-	-	-	-	-	3	6	5	1	3	2	1	-	-	-	-	-	-	1
Gastrotricha																								
<i>Chaetonotus</i> sp.	-	-	-	-	-	1	2	1	-	-	2	-	-	-	-	-	1	-	-	-	1	-	-	-
TOTAL ZOOPLANKTON	54	57	73	32	33	57	95	52	70	52	60	72	65	48	139	79	88	140	74	69	65	42	50	56

July in second year and was absent in post-paddy season (November-January). The abundance of *Lecane bulla* (0-9 n/l) at this site broadly followed a bimodal pattern of fluctuation with peak during August 2000 in first year and primary maxima (8 n/l) during February in second year. Further, *Lepadella patella* (0-6 n/l) occurred consistently almost during all months.

Cladocera: Another quantitatively important group was Cladocera, which ranged between 7-110 n/l (27 ± 22 n/l), 6-80 n/l (20 ± 15) and 9-44 n/l (18 ± 8) at Sites 1-3 respectively (Tables: 21-23). Maximum and minimum density of this group was seen at Sites 1 and 2 in April and September respectively during the first year of the study. The percentage composition of Cladocera varied between 4.4- 44.9 % ($23.5 \pm 11.3\%$), 12.9-65.0% ($29.2 \pm 13.5\%$) and 9.47-40.7% ($28.24 \pm 8.3\%$) at Sites 1-3 respectively. Maximum and minimum percentage was recorded at Site 2 (peat bog) during March in the second year and at Site 1 (pond) in May in the first year respectively. Further at Site 1, the density of this group in the first and the second year differed significantly and exhibited wider range during the first year i.e., between 7-110 n/l (27 ± 30 n/l). However during the second year of the study, it ranged between 11-46 n/l (26 ± 13 n/l). In contrast, at Sites 2 and 3, ranges and mean values were higher in the second year. It ranged between 6-27 n/l (15 ± 7 n/l) in the first year and between 9-80 n/l (25 ± 19 n/l) in the second year at Site 2 and between 8-24 n/l (16 ± 6 n/l) and 13-44 n/l (21 ± 9 n/l) respectively at Site 3. In the pond (Site 1), monthly variations in this group depicted broadly unimodal pattern in the first year (fig. 119) with peak density during April in the first year exhibiting sharp increase from February-April (18-110 n/l). Generally low density was registered from August-December in first year and September-January in second year depicting minima in December 2000. In second year, a bimodal pattern of density fluctuation occurred and primary and secondary maxima were registered during April (110 n/l) and July (44 n/l) respectively. At Site 2, density of Cladocera depicted unimodal pattern of their monthly fluctuations during the study period. Further in the first year, primary maxima was observed in May and there was gradual decline till September (minima) in this water body. However, a sharp increase was seen from February-March depicting the peak density, which was followed by generally low density till the end of the study period. At Site 3, cladocerans generally registered a low density with minor monthly fluctuations following a broadly bimodal pattern during the

study period. It depicted primary maxima (22 n/l) and the secondary (19 n/l) maxima in February and October respectively and the minima in September (8 n/l) during the first year. Similarly, peak density of cladoceran population was seen in April (44 n/l) and the secondary in July (32 n/l) with gradual decline during paddy and post-paddy seasons in second year of the study in this ecosystem.

Further, among members of this group, *Chydorus sphaericus* was registered at all sites in significant number and ranged between 0-16 n/l, 0-7 n/l and 0-17 n/l at Sites 1-3 respectively. Monthly variations of its density depicted a broadly unimodal pattern with its peak density in June at Site 1 and July at Sites 2 and 3 during the second year. At Site 1 (pond), *Ceriodaphnia reticulata* (0-99 n/l) showed its bloom during February-April (12-99 n/l) in the first year and it was present in significant abundance during this period in both the years. Along with this species *C. cornuta* (0-32 n/l) occurred with peak density during the second year and was noticed in significant density from January-May during both the years. At Site 2, zooplankton maxima in March 2001 was mainly due to *Daphniopsis* sp. (60 n/l), which exhibited a seasonal occurrence in early summer. The other quantitatively important species at this site are *Simocephalus serrulatus* (0-12 n/l) and *Alona guttata* (0-12 n/l), whose peak density also coincided with the *Daphniopsis* sp. bloom. At Site 3, *Pleuroxus similis* (0-11 n/l) and *Alona costata* (1-9 n/l), both depicting bimodal pattern of their monthly density fluctuation, occurred in higher abundance during the pre- and the post-monsoon period.

Copepoda: Population density of this group ranged widely at Site 1 (pond) between 6-950 n/l (134 ± 227 n/l) and with narrow ranges between 4-33 n/l (14 ± 7 n/l) and 5-24 n/l (13 ± 5 n/l) at Sites 2 (peat bog) and 3 (paddy-field) respectively. Their mean annual population densities exhibited the following trend in decreasing order i.e. Site 1 > Site 2 > Site 3. Further, they comprised between 17.4-92.4 % ($47.2 \pm 28.4\%$), 8.5-41.8% ($20.5 \pm 8.3\%$) and 8.6-30.0% ($17.6 \pm 8.3\%$) of total zooplankton at three sites respectively. Highest percentage composition was recorded at Site 1 in April during first year and the minimum was seen at Site 2 in April during second year of the study. Copepoda density exhibited unimodal pattern (Fig. 120) of their monthly variations at Sites 1 and 3 with peak values in April 2000 and 2001 respectively. However at Site 2, it followed a broadly bimodal pattern of fluctuation with peak density in March in first year and primary maxima also in March of second year. This was followed by secondary maxima in December (13 n/l) in first year and

during August and November in second year (14 n/l). Further at Site 1, maxima in the second year was of lower magnitude as it ranged less widely between 9-223 n/l (81 ± 93 n/l). While at Site 2 identical ranges and mean values were observed during the two years of study, at Site 3 it ranged more widely in second year between 6-55 n/l (18 ± 14 n/l).

Of this group, *Tropocyclops* sp. was quantitatively significant and its density ranged between 4-750 n/l at Site 1, 3-20 n/l at Site 2 and 3-32 n/l at Site 3. It was the main species contributing to the abundance of the copepods and followed unimodal pattern of its density variations at all three sites. While at Sites 1 and 2 its peak density was recorded during March first year, at Site 3 it was most abundant in April during the second year. However, it ranged less widely in the second year at Site 1 and 2 between (5-195 n/l) and (3-10 n/l) respectively but at Site 3 it ranged more widely during the second year (3-26 n/l). The other quantitatively important species of this group was *Eucyclops* sp. and was recorded only at Site 1 (0-20 n/l) and at Site 2 (0-4 n/l). Further, at Site 2, *Diaptomus* sp. occurred (0-14 n/l) occasionally. Besides, nauplius larvae of the copepods were recorded in significant density at Site 1 (0-200 n/l) with their peak density and the maxima coinciding with *Tropocyclops* sp. bloom. At Sites 2 and 3, the nauplius density ranged between 1-12 n/l and 0-18 n/l respectively during the study period.

Rhizopoda: Monthly abundance of the rhizopods also positively influenced total zooplankton density at all sites and ranged between 2-18 n/l (7 ± 4), 4-32 n/l (14 ± 7) and 5-24 n/l (13 ± 5 n/l) at Sites 1-3 respectively. It varied broadly with a unimodal pattern at Site 1 (pond), broadly bimodal patterns at Sites 2 (peat bog) and trimodal pattern at Site 3 (paddy-field). Population density of the Rhizopoda remained generally low during the pre-monsoon period at Sites 2 and 3 and during the monsoon at Site 1 with their minima depicted during August 2000, February 2001 and May 2000 at Sites 1-3 respectively. At Site 1, it attained peak in November and remained relatively high during the post-monsoon period. Rhizopoda was a prominent group at Site 2 (peat bog) with its percentage composition ranging between 4.07-45.16%. Its composition gradually increased from February till its maxima in August 2000 in this ecosystem. Rhizopoda was represented by *Diffugia* sp. at all three sites with 0-4 n/l at Site 1, 1-9 n/l at Site 2 and 0-6 n/l at Site 3. Further *Euglypha* sp. at Site 1 (0-5 n/l), *Diffugia lebes* at Site 2 (0-12 n/l) and *Arcella megastoma* at Site 3 (0-11 n/l) constituted quantitatively important taxa. Other species

occurred occasionally in smaller densities throughout the study period. Among other groups of zooplankton, Ostracoda represented by *Cypris* sp. occurred between 0-3 n/l at all the sites and Nematoda 0-4 n/l at Site 1, 0-4 n/l at Site 2 and 0-6 n/l at Site 3 were recorded. Further, the Gastrotricha represented by *Chaetonotus* sp. was observed at Site 1 (0-3 n/l) and Site 3 (0-2 n/l) occasionally.

V. ECOLOGICAL CORRELATIONS (BIOTIC VS ABIOTIC AND BIOTIC VS. BIOTIC)

The coefficient of correlation (r) computed between various abiotic factors and biotic groups as well as among biotic components at three selected ecosystems viz. pond (Site 1), peat bog (Site 2) and paddy-field (Site 3) indicated by r_1 , r_2 and r_3 respectively are presented in Tables: 25-30. Out of 280 instances of correlations computed between 20 abiotic and 14 biotic components, 54 and 52 instances of significant correlations were observed at Sites 1 and 2 respectively. However, at Site 3, only 34 instances of significant correlations were registered out of 304 instances computed between 19 abiotic factors and 16 biotic groups. Further, at Site 1, among the abiotic factors, pH recorded the maximum instances of significant correlations i.e., with nine biotic groups, while Ostracoda showed significant relationship with eight abiotic parameters in this ecosystem. However, total hardness and Euglenophyceae did not show any significant correlation with studied biotic and abiotic factors respectively. At Site 2, transparency showed its impact on seven biotic components and Dinophyceae, in turn, was influenced by eleven abiotic factors. While pH had no significant impact on any of the biotic components studied, total zooplankton and Ostracoda were influenced by only one abiotic factor each. At Site 3, total hardness and chloride exerted their influence on five biotic components each while Euglenophyceae and Cladocera, in turn, received the impact of five abiotic factors each. Specific conductivity, pH, sodium, nitrate and dissolved organic matter had no significant impact on any of the studied biotic components. Similarly, Dinophyceae, Rhizopoda and Gastrotricha did not significantly correlate with any of the abiotic factors studied.

Among the biotic factors, 91 instances each of simple correlations were computed among 14 biotic groups, of which 24 and 18 significant correlations were recorded at Sites 1 and 2 respectively. Of these, Bacillariophyceae and Cladocera exhibited highest number of correlations (7 each) with other biotic components at Site 1 (pond), while Euglenophyceae and Nematoda did not register any significant correlation with other biotic

TABLE 25: CORRELATION COEFFICIENT (r_t) BETWEEN ABIOTIC AND BIOTIC FACTORS AT SITE 1 (POND)

	Net plankton	Phytoplankton	Zooplankton	Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae	Rotifera	Cladocera	Copepoda	Rhizopoda	Ostracoda	Nematoda	Gastrotricha
Water Temperature	-0.095	-0.486**	0.056	-0.332	-0.232	-0.444***	-0.18	0.307	0.18	0.036	-0.104	0.545*	-0.26	0.405***
Rainfall	-0.177	-0.574*	0.005	-0.254	-0.254	-0.568*	-0.03	0.383	0.06	-0.005	-0.359	0.624*	-0.15	0.309
Transparency	0.062	0.351	-0.046	0.239	0.191	0.312	0.058	-0.387	-0.144	-0.028	0.173	-0.720*	0.108	-0.373
Specific Conductivity	0.201	-0.517*	0.342	0.359	-0.496**	-0.519*	-0.14	0.514**	0.35	0.327	-0.385	0.591*	0.034	0.114
pH	-0.407***	0.531*	-0.538*	-0.515*	0.531*	0.554*	0.192	-0.314	-0.520*	-0.527*	0.491**	-0.277	-0.11	-0.188
Dissolved Oxygen	-0.076	0.692*	-0.276	-0.071	0.414***	0.714*	0.341	-0.299	-0.382	-0.26	0.479**	-0.460***	0.184	-0.234
Free CO ₂	0.025	-0.159	0.07	-0.107	-0.113	-0.125	-0.26	0.241	0.269	0.039	0.125	0.483**	-0.2	0.844*
Total Alkalinity	0.305	-0.177	0.337	0.09	-0.282	-0.115	-0.33	-0.014	0.497**	0.312	-0.025	0.332	-0.12	0.307
Total Hardness	-0.135	-0.284	-0.042	0.278	-0.214	-0.33	-0.05	0.251	0.055	-0.053	-0.235	-0.07	0.272	0.259
Calcium	0.386	-0.308	0.452***	0.31	-0.435***	-0.271	0.105	0.513**	0.434***	0.435***	-0.238	0.412***	0.109	0.056
Magnesium	-0.403	-0.143	-0.334	-0.132	0.022	-0.165	-0.03	0.161	-0.226	-0.337	-0.152	-0.139	0.114	0.253
Sodium	0.027	-0.115	0.059	0.247	-0.173	-0.125	0.043	0.143	0.069	0.058	-0.192	-0.217	0.13	-0.046
Potassium	-0.194	-0.342	-0.08	0.279	-0.028	-0.375	-0.03	0.403	0.104	-0.101	-0.284	0.094	0.267	0.354
Chloride	-0.299	0.004	-0.281	-0.148	0.289	-0.091	-0.09	-0.082	-0.322	-0.273	0.206	-0.007	-0.03	0.418***
Sulphate	0.34	-0.484**	0.461***	0.097	-0.339	-0.492**	0.018	0.121	0.394	0.462***	-0.512**	0.411***	-0.32	-0.048
Phosphate	0.481**	-0.225	0.516*	0.520*	-0.322	-0.257	-0.19	0.143	0.424***	0.519*	-0.515*	0.132	0.09	-0.253
Nitrate	-0.188	0.03	-0.185	0.014	-0.09	0.072	0.278	0.643*	-0.101	-0.206	0.141	0.42	0.341	0.037
Silicate	-0.089	0.137	-0.124	-0.371	0.226	0.156	0.081	-0.35	-0.218	-0.11	0.333	-0.2	-0.08	-0.098
Dissolved Organic Matter	0.347	0.045	0.311	-0.095	0.055	0.057	-0.19	-0.029	0.292	0.303	0.172	0.223	-0.27	-0.119
Total Dissolved Solids	0.524*	-0.09	0.517*	0.449***	-0.294	-0.084	0.078	-0.14	0.4	0.520*	-0.075	-0.129	0.313	-0.324

P < 0.01 (*)

P < 0.02 (**)

P < 0.05 (***)

TABLE 26: COEFFICIENT CORRELATION (r_2) BETWEEN ABIOTIC AND BIOTIC FACTORS AT SITE 2 (PEAT BOG)

	Net plankton	Phytoplankton	Zooplankton	Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae	Dinophyceae	Rotifera	Cladocera	Copepoda	Rhizopoda	Ostracoda	Nematoda
Water temperature	0.428***	0.385	0.302	0.548*	-0.104	0.302	-0.247	0.332	0.355	-0.01	-0.142	0.579*	0.048	0.474**
Rainfall	0.579*	0.535*	0.309	0.690*	-0.136	0.468***	-0.229	0.672*	0.344	0.084	-0.208	0.522*	0.016	0.235
Transparency	-0.712*	-0.699*	-0.103	-0.747*	-0.144	-0.564*	0.389	-0.487**	-0.407***	0.256	0.165	-0.597*	-0.044	-0.116
Specific Conductivity	-0.505**	-0.521*	0.105	-0.460***	-0.019	-0.546*	-0.133	0.634*	-0.167	0.397	0.352	-0.695*	0.102	-0.387
PH	0.139	0.162	-0.157	0.219	0.028	0.107	-0.151	-0.207	0.229	-0.343	-0.374	0.392	-0.001	0.368
Dissolved Oxygen	-0.16	-0.15	-0.071	-0.418***	0.623*	-0.299	0.675*	-0.461***	-0.215	0.027	-0.189	0.068	0.067	0.051
Free CO ₂	0.042	0.022	0.136	0.103	0.093	-0.102	-0.194	0.462***	0.292	0.003	0.053	0.058	0.365	0.076
Total Alkalinity	-0.246	-0.246	-0.002	-0.193	0.096	-0.335	-0.09	0.252	0.438***	-0.117	-0.059	-0.071	0.001	-0.119
Total Hardness	-0.39	-0.468***	0.531*	-0.463***	-0.014	-0.451***	-0.061	-0.263	-0.145	0.670*	0.508**	-0.352	0.298	0.256
Calcium	-0.319	-0.348	0.196	-0.467***	0.212	-0.361	0.074	-0.508**	-0.042	0.167	0.543*	-0.287	-0.017	-0.065
Magnesium	-0.316	-0.365	0.328	-0.303	-0.121	-0.337	-0.032	-0.068	-0.239	0.556*	0.256	-0.326	0.285	0.349
Sodium	-0.21	-0.259	0.334	-0.147	-0.127	-0.266	-0.579	0.122	0.073	0.466***	0.490**	-0.537*	0.247	-0.224
Potassium	-0.307	-0.329	0.143	-0.319	0.014	-0.343	0.292	-0.212	-0.439***	0.518*	0.39	-0.651*	0.021	-0.467***
Chloride	-0.061	-0.062	0.011	-0.151	-0.011	0.027	-0.004	-0.820*	0.171	-0.154	-0.066	0.209	0.072	0.456***
Sulphate	-0.292	-0.272	-0.142	-0.369	0.324	-0.383	0.372	-0.116	-0.503**	0.14	0.251	-0.435***	0.17	-0.515*
Phosphate	0.081	0.058	0.159	0.142	-0.079	0.021	0.014	0.650*	-0.127	0.232	0.317	-0.205	0.137	-0.271
Nitrate	-0.11	-0.087	-0.161	0.002	0.02	-0.162	-0.37	0.063	0.213	-0.313	-0.023	0.05	-0.068	-0.12
Silicate	-0.118	-0.077	-0.28	-0.081	-0.091	-0.025	0.184	0.343	0.083	-0.246	-0.107	-0.144	-0.548*	-0.189
Dissolved Organic Matter	0.039	0.049	-0.066	0.186	-0.082	-0.021	0.01	0.473**	-0.067	-0.022	0.088	-0.144	-0.071	-0.009
Total Dissolved Solids	-0.232	-0.187	-0.312	-0.371	0.238	-0.164	0.386	-0.512**	-0.395	-0.177	-0.019	-0.136	0.132	-0.234

P < 0.01 (*)

P < 0.02 (**)

P < 0.05 (***)

TABLE 27: CORRELATION COEFFICIENT (r_1) BETWEEN ABIOTIC AND BIOTIC FACTORS AT SITE 3 (PADDY-FIELD)

	Net plankton	Phytoplankton	Zooplankton	Chlorophyceae	Bacillariophyceae	Chrysophyceae	Cyanophyceae	Euglenophyceae	Dinophyceae	Rotifera	Cladocera	Copepoda	Rhizopoda	Ostracoda	Nematoda	Gastrotricha
Water Temperature	-0.699*	-0.748*	0.271	-0.094	-0.193	0.021	-0.703*	0.22	-0.21	0.454***	-0.071	0.189	-0.01	0.182	-0.231	0.116
Rainfall	-0.359	-0.411***	0.28	0.025	-0.396	-0.181	-0.281	0.115	-0.18	0.504**	-0.192	0.153	0.201	0.113	-0.35	0.391
Specific Conductivity	-0.213	-0.243	0.159	0.008	-0.399	0.323	-0.117	0.51	-0.15	-0.043	0.154	0.338	-0.13	-0.018	0.277	-0.05
pH	-0.37	-0.324	-0.225	-0.385	0.257	0.157	-0.373	-0.229	0.265	0.149	-0.326	-0.353	-0.18	-0.262	-0.186	0.026
Dissolved Oxygen	0.321	0.265	0.277	0.297	0.4	0.104	0.073	-0.223	0.221	-0.104	0.461***	0.264	0.302	0.36	0.26	-0.14
Free CO ₂	0.01	-0.02	0.149	0.149	-0.177	0.359	0.005	0.477**	0.335	0.281	-0.158	0.183	-0.01	0.01	-0.031	-0.03
Total Alkalinity	0.033	-0.032	0.331	0.525*	-0.258	0.157	-0.037	0.451***	-0.37	0.256	-0.03	0.387	0.185	0.162	0.116	0.247
Total hardness	-0.202	-0.3	0.510**	0.386	-0.406***	-0.011	-0.241	0.587*	-0.17	0.24	0.277	0.609*	0.175	0.478**	0.138	-0.01
Calcium	-0.277	-0.273	-0.016	0.085	-0.242	0.132	-0.222	0.451***	0.066	0.375	-0.547*	-0.081	0.057	-0.173	-0.28	0.393
Magnesium	-0.116	-0.218	0.531	0.366	-0.331	-0.054	-0.176	0.443***	-0.19	0.113	0.481**	0.654*	0.161	0.552*	0.245	-0.15
Sodium	-0.177	-0.189	0.075	0.235	-0.439	-0.366	-0.065	0.066	-0.23	-0.076	0.009	0.122	0.169	0.273	0.219	0.108
Potassium	0.035	0.043	-0.044	0.546*	-0.277	0.258	0.052	0.22	-0.13	-0.098	-0.094	0.127	-0.18	0.145	0.158	-0.25
Chloride	0.296	0.21	0.429***	0.651*	0.074	0.447***	0.068	0.194	0.1	0.154	0.357	0.410***	0.25	0.306	0.410***	-0.18
Sulphate	0.082	0.012	0.356	0.329	-0.014	0.460***	-0.047	0.087	0.317	0.194	0.169	0.369	0.201	0.264	0.199	-0.07
Phosphate	0.128	0.198	-0.365	-0.155	-0.138	-0.293	0.293	0.038	0.075	-0.477**	-0.201	-0.002	-0.27	-0.185	-0.274	-0.05
Nitrate	-0.119	-0.119	0.001	0.143	-0.269	0.067	-0.045	0.07	-0.14	-0.054	-0.032	0.092	0.012	0.145	-0.119	-0.1
Silicate	-0.178	-0.276	0.515*	-0.066	-0.241	-0.271	-0.183	0.046	-0.21	0.214	0.447***	0.576*	0.185	0.429***	-0.157	-0.02
Dissolved Organic Matter	-0.213	-0.17	-0.212	-0.157	0.071	-0.346	-0.168	-0.297	-0.16	-0.167	-0.143	-0.098	-0.13	-0.043	-0.392	0.053
Total Dissolve Solids	-0.261	-0.184	-0.388	-0.055	-0.331	-0.416***	-0.046	-0.086	0.082	-0.298	-0.439***	-0.174	-0.21	0.06	-0.142	0.099

P < 0.01 (*)

P < 0.02 (**)

P < 0.05 (***)

TABLE 28: CORRELATION MATRIX (r_1) BETWEEN BIOTIC FACTORS AT SITE 1 (POND)

	Net plankton	Phytoplankton	Zooplankton	Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae	Rotifera	Cladocera	Copepoda	Rhizopoda	Ostracoda	Nematoda	Gastrotricha
Net plankton	1.000	-0.066	0.955*	0.535*	-0.290	-0.071	-0.159	-0.290	0.792*	0.957*	-0.217	-0.019	-0.095	-0.112
Phytoplankton		1.000	-0.359	-0.175	0.786*	0.967*	0.253	-0.267	-0.445***	-0.347	0.661*	-0.299	0.117	-0.111
Zooplankton			1.000	0.553*	-0.505**	-0.353	-0.224	-0.192	0.873*	0.998*	-0.399	0.071	-0.124	-0.072
Chlorophyceae				1.000	-0.418***	-0.256	-0.133	-0.034	0.520*	0.548*	-0.323	-0.054	0.283	-0.002
Bacillariophyceae					1.000	0.654*	-0.023	-0.302	-0.593*	-0.485**	0.458***	-0.177	-0.005	-0.075
Cyanophyceae						1.000	0.350	-0.204	-0.416***	-0.345	0.711*	-0.292	0.087	-0.107
Euglenophyceae							1.000	0.271	-0.285	-0.222	0.245	-0.066	0.162	-0.086
Rotifera								1.000	-0.009	-0.226	-0.047	0.576	0.005	0.431***
Cladocera									1.000	0.845*	-0.360	0.049	-0.260	0.167
Copepoda										1.000	-0.410***	0.056	-0.112	-0.110
Rhizopoda											1.000	-0.089	0.077	0.202
Ostracoda												1.000	0.025	0.501**
Nematoda													1.000	-0.117
Gastrotricha														1.000

P < 0.01 (*)

P < 0.02 (**)

P < 0.05 (***)

TABLE 29: CORRELATION MATRIX (r_2) BETWEEN BIOTIC FACTORS AT SITE 2 (PEAT BOG)

	Net plankton	Phytoplankton	Zooplankton	Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae	Dinophyceae	Rotifera	Cladocera	Copepoda	Rhizopoda	Ostracoda	Nematoda
Net plankton	1.000	0.989*	0.088	0.872*	0.232	0.915*	-0.233	-0.079	0.105	-0.194	-0.017	0.590*	-0.069	0.134
Phytoplankton		1.000	-0.058	0.874*	0.242	0.927*	-0.220	-0.120	0.050	-0.310	-0.094	0.565*	-0.131	0.088
Zooplankton			1.000	-0.001	-0.068	-0.068	-0.095	0.284	0.374	0.787*	0.530*	0.181	0.421***	0.316
Chlorophyceae				1.000	-0.138	0.822*	-0.470***	-0.043	0.055	-0.212	-0.057	0.465***	-0.032	0.061
Bacillariophyceae					1.000	-0.037	0.357	0.038	0.042	-0.218	-0.030	0.254	0.034	0.101
Cyanophyceae						1.000	-0.234	-0.215	0.029	-0.263	-0.102	0.478**	-0.222	0.053
Euglenophyceae							1.000	-0.291	0.000	-0.054	-0.319	0.142	-0.221	0.222
Dinophyceae								1.000	-0.338	0.503**	0.402	-0.337	0.231	-0.464***
Rotifera									1.000	-0.075	-0.115	0.381	-0.065	0.636*
Cladocera										1.000	0.412***	-0.317	0.346	-0.066
Copepoda											1.000	-0.242	0.266	-0.260
Rhizopoda												1.000	0.103	0.564*
Ostracoda													1.000	-0.008
Nematoda														1.000

P < 0.01 (*)

P < 0.02 (**)

P < 0.05 (***)

TABLE 30: CORRELATION MATRIX (r_3) BETWEEN BIOTIC FACTORS AT SITE 3 (PADDY-FIELD)

	Net plankton	Phytoplankton	Zooplankton	Chlorophyceae	Bacillariophyceae	Chrysophyceae	Cyanophyceae	Euglenophyceae	Dinophyceae	Rotifera	Cladocera	Copepoda	Rhizopoda	Ostracoda	Nematoda	Gastrotricha
Net plankton	1.000	0.981*	0.065	0.142	0.337	-0.022	0.881*	-0.118	0.012	-0.051	0.144	0.078	0.113	-0.051	-0.012	-0.144
Phytoplankton		1.000	-0.130	0.069	0.333	-0.042	0.917*	-0.155	0.036	-0.179	0.007	-0.072	-0.014	-0.181	-0.041	-0.154
Zooplankton			1.000	0.370	0.011	0.099	-0.214	0.189	-0.123	0.657*	0.703*	0.767*	0.658*	0.675*	0.148	0.057
Chlorophyceae				1.000	-0.047	0.452***	-0.089	0.078	-0.149	0.127	0.106	0.423***	0.269	0.330	0.599*	0.020
Bacillariophyceae					1.000	0.052	-0.028	-0.454***	0.376	0.040	0.051	-0.061	0.010	-0.142	0.090	0.020
Chrysophyceae						1.000	-0.158	0.220	-0.086	0.117	-0.036	0.030	0.034	-0.150	0.596*	0.074
Cyanophyceae							1.000	-0.030	-0.090	-0.238	-0.029	-0.131	-0.066	-0.192	-0.187	-0.175
Euglenophyceae								1.000	-0.051	0.308	-0.055	0.157	-0.025	0.002	-0.079	0.005
Dinophyceae									1.000	-0.034	-0.146	-0.127	-0.002	0.017	-0.139	-0.111
Rotifera										1.000	0.041	0.149	0.533*	0.221	-0.187	0.212
Cladocera											1.000	0.712	0.335	0.595*	0.258	-0.286
Copepoda												1.000	0.200	0.638*	0.167	-0.121
Rhizopoda													1.000	0.457***	0.131	0.394
Ostracoda														1.000	0.155	-0.156
Nematoda															1.000	-0.040
Gastrotricha																1.000

P < 0.01 (*)

P < 0.02 (**)

P > 0.05 (***)

groups. At Site 2, Chlorophyceae and Rhizopoda depicted significant correlation with five other biotic components each, while, Bacillariophyceae did not exhibit a significant relationship with any other group. At Site 3 (paddy-field), 120 instances of correlations were computed of which only 17 significant correlations were recorded. Highest number (5 instances) of correlations was depicted by zooplankton while Dinophyceae and Gastrotricha did not exhibit any significant relationship with other biotic communities.

VI. MULTIPLE CORRELATIONS

Multiple regressions and step-wise regressions between net plankton (Y), phytoplankton (Yp) and zooplankton (Yz) vs. twenty abiotic factors at Site 1 (pond) and Site 2 (peat bog), i.e., water temperature (x_1), rainfall (x_2), transparency (x_3), specific conductivity (x_4), pH (x_5), dissolved oxygen (x_6), free carbon dioxide (x_7), total alkalinity (x_8), total hardness (x_9), calcium (x_{10}), magnesium (x_{11}), sodium (x_{12}), potassium (x_{13}), chloride (x_{14}), sulphate (x_{15}), phosphate (x_{16}), nitrate (x_{17}), silicate (x_{18}) dissolved organic matter (x_{19}) and total dissolved solids (x_{20}) were computed. On the other hand at Site 3 (paddy-field), multiple and step-wise regression between the three biotic communities vs. 19 abiotic factors were computed as transparency was not applicable in this ecosystem. The details of the regression analysis are mentioned below:

SITE 1 (POND)

Net plankton (Y) vs. 20 abiotic factors (x_1 - x_{20}): cumulative

$$Y = 10148.4927 - 7.8099 (x_1) - 81.1154 (x_2) - 0.8615 (x_3) - 5.5589 (x_4) + 18.4557(x_5) - 771.0915 (x_6) - 95.2529 (x_7) + 5.8172 (x_8) + 3.4477 (x_9) + 0.7639 (x_{10}) - 84.2127 (x_{11}) + 3.0008 (x_{12}) - 82.6531 (x_{13}) - 5.3548 (x_{14}) + 269.4041 (x_{15}) - 5968.6128 (x_{16}) - 30.7952 (x_{17}) + 1.7371 (x_{18}) + 34.0556 (x_{19}) + 25.7100 (x_{20})$$

$$R^2 = 0.7373$$

Therefore, the stated twenty variables accounted for 73% of variations of net plankton densities. However, step-wise regression indicated the following:

I. Net Plankton vs. nineteen abiotic variables (x_1 - x_{19})

$$Y = 9769.0804 - 6.9434 (x_1) - 81.1423 (x_2) - 0.7407 (x_3) - 14.8350 (x_4) + 17.4647(x_5) - 749.8215 (x_6) - 89.2870 (x_7) + 6.6458 (x_8) + 4.0107 (x_9) + 2.9972 (x_{10}) - 79.7403 (x_{11})$$

$$+1.7593 (x_{12}) - 82.3085 (x_{13}) - 8.3140 (x_{14}) + 247.6948 (x_{15}) - 5782.7643 (x_{16}) - 3177.0690 (x_{17}) + 1.8965 (x_{18}) + 38.8417 (x_{19})$$

$$R^2 = 0.8244$$

The stated nineteen variables accounted for 82% of the variations in net plankton densities at this site.

II. Net plankton vs. eighteen abiotic variables (x_1 - x_{18})

$$Y = 11414.9789 - 12.3866 (x_1) - 71.3017 (x_2) - 1.7270 (x_3) - 18.6551 (x_4) + 20.7807 (x_5) - 839.6868 (x_6) - 116.5815 (x_7) + 1.4348 (x_8) - 0.6719 (x_9) + 15.1216 (x_{10}) - 88.5086 (x_{11}) + 8.3169 (x_{12}) - 74.4952 (x_{13}) + 12.1041 (x_{14}) + 308.7073 (x_{15}) - 7037.1095 (x_{16}) - 3005.5826 (x_{17}) + 1.0615 (x_{18})$$

$$R^2 = 0.8550$$

Above eighteen factors cumulatively accounted for 85% of net plankton density variations.

III. Net plankton vs. seventeen abiotic variables (x_1 - x_{17})

$$Y = 12262.8011 - 9.1480 (x_1) - 74.4421 (x_2) - 2.0262 (x_3) - 21.0934 (x_4) + 21.7896 (x_5) - 876.3727 (x_6) - 124.9291 (x_7) - 0.3403 (x_8) - 5.7630 (x_9) + 19.5603 (x_{10}) - 105.4976 (x_{11}) + 13.2984 (x_{12}) - 69.6665 (x_{13}) + 14.6095 (x_{14}) + 354.1187 (x_{15}) - 7580.0889 (x_{16}) - 3311.8069 (x_{17})$$

$$R^2 = 0.8801$$

Above seventeen variables accounted for 88% of the variation in the net plankton density.

IV. Net plankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y = 11078.3289 + 1.1022 (x_1) - 127.9710 (x_2) - 0.2992 (x_3) - 10.6844 (x_4) + 20.8097 (x_5) - 898.3551 (x_6) - 146.7409 (x_7) + 7.1948 (x_8) + 25.3849 (x_9) + 29.7194 (x_{10}) + 33.3327 (x_{11}) + 8.7133 (x_{12}) - 146.0558 (x_{13}) + 39.8736 (x_{14}) + 179.1884 (x_{15}) - 9361.9720 (x_{16})$$

$$R^2 = 0.7511$$

The stated sixteen variables accounted for 75% of the variations in net plankton densities.

V. Net plankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y = 4624.9407 + 3.0991 (X_1) - 67.0479 (X_2) + 0.1774 (X_3) - 2.1168 (X_4) + 18.8732 (X_5) - 449.1135 (X_6) - 69.6217 (X_7) + 6.0401 (X_8) + 29.5507 (X_9) + 8.8529 (X_{10}) - 22.2480 (X_{11}) + 14.2826 (X_{12}) - 112.2904 (X_{13}) + 28.0235 (X_{14}) + 24.7135 (X_{15})$$

$$R^2 = 0.5525$$

The above fifteen variables accounted for 55% of the variations in the density of net plankton.

VI. Net plankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y = 4653.0921 + 1.7573 (X_1) - 66.5810 (X_2) + 0.2253 (X_3) - 2.0735 (X_4) + 18.9961 (X_5) - 450.4325 (X_6) - 70.5580 (X_7) + 6.0368 (X_8) + 29.7336 (X_9) + 9.0827 (X_{10}) - 21.2779 (X_{11}) - 12.7788 (X_{12}) - 113.2906 (X_{13}) + 28.3827 (X_{14})$$

$$R^2 = 0.6083$$

Cumulative impact of the above fourteen variables on the net plankton densities at this site was up to 60%.

VII. Net plankton vs. thirteen abiotic variables (x_1 - x_{13})

$$Y = 4488.7709 - 4.0530 (X_1) - 58.4855 (X_2) + 0.4616 (X_3) - 0.3542 (X_4) + 17.2095 (X_5) - 445.6627 (X_6) - 58.9831 (X_7) + 12.4158 (X_8) + 25.0463 (X_9) + 16.2314 (X_{10}) - 26.4794 (X_{11}) + 6.5520 (X_{12}) - 116.7153 (X_{13})$$

$$R^2 = 0.6408$$

The above thirteen abiotic factors accounted for 64% of variations of the net plankton density.

VIII. Net plankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y = 5818.6400 - 21.5839 (x_1) + 0.2203 (x_2) - 1.1449 (x_3) - 3.9462 (x_4) + 20.3140 (x_5) - 561.7452 (x_6) - 43.7596 (x_7) + 5.6619 (x_8) + 4.9692 (x_9) + 3.6084 (x_{10}) - 114.7969 (x_{11}) - 7.1699 (x_{12})$$

$$R^2 = 0.5629$$

The above twelve factors as a whole accounted for 56% of the variations of the net plankton density.

IX. Net plankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y = 5925.7312 - 19.1199 (x_1) - 0.2849 (x_2) - 1.1991 (x_3) - 4.3735 (x_4) + 19.9427 (x_5) - 573.9912 (x_6) - 41.5332 (x_7) + 5.1037 (x_8) + 4.4791 (x_9) + 4.1835 (x_{10}) - 122.1352 (x_{11})$$

$$R^2 = 0.601$$

The above-mentioned eleven variables accounted for 60% of the variations in the net plankton density.

X. Net plankton vs. ten abiotic variables (x_1 - x_{10})

$$Y = 4766.4363 - 12.8765 (x_1) + 0.8102 (x_2) - 1.2942 (x_3) + 0.9095 (x_4) + 16.7146 (x_5) - 526.0305 (x_6) - 53.1146 (x_7) + 2.3938 (x_8) + 13.6938 (x_9) + 33.1465(x_{10})$$

$$R^2 = 0.5592$$

The stated ten abiotic factors accounted for 55% of the variations of the net plankton density.

SITE 2 (PEAT BOG)

Net plankton (Y) vs. 20 abiotic factors (x₁-x₂₀): cumulative

The multiple regression value between net plankton (Y_N) with the twenty abiotic variables (x₁-x₂₀) at Site 2 are represented by the following regression equation:

$$Y = 3060.7928 + 0.6287 (x_1) - 1.2880 (x_2) - 0.1167 (x_3) - 8.8465 (x_4) + 5.7953 (x_5) - 280.0917 (x_6) + 31.2211 (x_7) - 2.5960 (x_8) - 9.1219 (x_9) + 0.0941 (x_{10}) + 55.0891 (x_{11}) + 46.3766 (x_{12}) + 3.5738 (x_{13}) + 14.0247 (x_{14}) + 11.5279 (x_{15}) + 136.8033 (x_{16}) - 18.1269 (x_{17}) - 0.7744 (x_{18}) + 11.0165 (x_{19}) + 248.3719 (x_{20})$$

$$R^2 = 0.9509$$

Therefore, the stated twenty variables accounted for 95% of the variations of net plankton densities at this study site. However, step-wise regression indicated the following:

I. Net Plankton vs. nineteen abiotic variables (x₁-x₁₉)

$$Y = 2878.4118 + 1.2042 (x_1) - 5.9759 (x_2) + 0.3361 (x_3) - 8.9500 (x_4) + 7.3873 (x_5) - 293.7353 (x_6) + 32.0680 (x_7) - 2.3473 (x_8) - 8.4649 (x_9) + 0.7540 (x_{10}) - 31.1422 (x_{11}) + 55.0259 (x_{12}) + 2.2812 (x_{13}) + 13.0978 (x_{14}) + 1.0368 (x_{15}) + 71.3559 (x_{16}) + 325.6599 (x_{17}) + 5.1759 (x_{18}) + 17.8495 (x_{19})$$

$$R^2 = 0.9410$$

The stated nineteen variables accounted for 94% of the variations in net plankton densities.

II. Net plankton vs. eighteen abiotic variables (x₁-x₁₈)

$$Y = 2967.8314 + 10.1467 (x_1) - 10.8023 (x_2) - 0.2353 (x_3) - 11.7792 (x_4) + 8.8602 (x_5) - 275.3210 (x_6) + 30.3586 (x_7) - 0.4193 (x_8) - 9.9005 (x_9) + 14.2147 (x_{10}) - 51.9517 (x_{11}) + 49.8891 (x_{12}) + 14.2648 (x_{13}) - 5.3301 (x_{14}) + 8.0610 (x_{15}) + 343.6016 (x_{16}) + 1195.5575 (x_{17}) + 16.8447 (x_{18})$$

$$R^2 = 0.9310$$

Further, above eighteen factors cumulatively accounted for 93% of net plankton density variations.

III. Net plankton vs. seventeen abiotic variables (x₁-x₁₇)

$$Y = 2871.2879 + 3.2687 (x_1) - 1.3561 (x_2) - 0.3331 (x_3) - 10.0387 (x_4) - 6.4062 (x_5) - 239.4196 (x_6) + 31.8490 (x_7) - 2.3779 (x_8) - 6.9180 (x_9) + 3.7219 (x_{10}) - 51.7908 (x_{11}) +$$

$$41.7377 (x_{12}) + 11.8566 (x_{13}) - 20.1573 (x_{14}) + 29.9119 (x_{15}) + 780.4203 (x_{16}) + 625.9756 (x_{17})$$

$$R^2 = 0.9194$$

Above seventeen variables accounted for 91% of the variation in the net plankton density.

IV. Net plankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y = 2689.5931 + 4.0366 (x_1) + 1.0589 (x_2) - 0.2184 (x_3) - 9.4747 (x_4) - 4.8557 (x_5) - 229.2226 (x_6) + 27.4531 (x_7) - 3.0472 (x_8) - 5.9972 (x_9) + 1.0852 (x_{10}) + 54.5784 (x_{11}) + 41.8432 (x_{12}) + 7.9721 (x_{13}) - 16.0358 (x_{14}) - 2.2218 (x_{15}) + 641.5034 (x_{16})$$

$$R^2 = 0.9162$$

Therefore, the stated sixteen variables also accounted for 91% of the variations of net plankton densities.

V. Net plankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y = 2671.065 + 6.974889 (x_1) - 4.28441 (x_2) + 0.311803 (x_3) - 8.73977 (x_4) - 4.58603 (x_5) - 256.127 (x_6) + 18.76391 (x_7) - 2.5531 (x_8) - 5.81626 (x_9) - 2.06771 (x_{10}) - 46.5554 (x_{11}) + 40.20115 (x_{12}) + 6.534626 (x_{13}) - 5.03973 (x_{14}) + 42.05348 (x_{15})$$

$$R^2 = 0.9121$$

The cumulative impact of above fifteen abiotic variables was also up to 91% on the density of net plankton at this site.

VI. Net plankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y = 2650.9867 + 4.8057 (x_1) - 2.2009 (x_2) + 0.1974 (x_3) - 8.4038 (x_4) - 3.9566 (x_5) - 244.7778 (x_6) + 27.4298 (x_7) - 1.9103 (x_8) - 6.9158 (x_9) - 0.4068 (x_{10}) - 62.3633 (x_{11}) + 43.1821 (x_{12}) + 11.6125 (x_{13}) - 5.5423 (x_{14})$$

$$R^2 = 0.90439$$

This step indicated that the above fourteen variables accounted for 90% of the density variations.

VII. Net plankton vs. thirteen abiotic variables (x_1 - x_{13})

$$Y = 2597.9227 + 4.8489 (x_1) - 2.9757 (x_2) + 0.2668 (x_3) - 8.3583 (x_4) - 3.6874 (x_5) - 241.4094 (x_6) + 27.7999 (x_7) - 1.8885 (x_8) - 7.0235 (x_9) - 1.2102 (x_{10}) - 61.7035 (x_{11}) + 43.3780 (x_{12}) + 11.5925 (x_{13})$$

$$R^2 = 0.9039$$

The above thirteen abiotic factors also accounted for 90% of variations of the net plankton density.

VIII. Net plankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y = 2737.6038 + 2.7342 (x_1) - 2.8904 (x_2) + 0.4175 (x_3) - 8.1812 (x_4) - 1.9668 (x_5) - 263.7750 (x_6) + 32.1647 (x_7) - 2.5636 (x_8) - 8.3436 (x_9) - 1.1306 (x_{10}) - 56.0818 (x_{11}) + 44.1088 (x_{12})$$

$$R^2 = 0.8944$$

The above twelve factors as a whole accounted for 89% of the variations of net plankton density.

IX. Net plankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y = 2821.1779 + 4.6660 (x_1) - 7.4373 (x_2) + 0.3567 (x_3) - 8.8260 (x_4) - 1.0014 (x_5) - 259.0947 (x_6) + 16.0196 (x_7) - 1.1384 (x_8) - 6.4842 (x_9) + 2.3540 (x_{10}) - 37.0496 (x_{11})$$

$$R^2 = 0.8208$$

The cumulative impact of the above eleven factors on the variation of the net plankton density was up to 82%.

X. Net plankton vs. ten abiotic variables (x_1 - x_{10})

$$Y = 2618.4506 + 5.5856 (x_1) - 10.2502 (x_2) + 0.5484 (x_3) - 8.5442 (x_4) - 1.5676 (x_5) - 236.2034 (x_6) + 14.7428 (x_7) - 1.0700 (x_8) - 5.0542 (x_9) - 7.2921 (x_{10})$$

$$R^2 = 0.8124$$

The stated ten abiotic factors accounted for 81% of the variations in net plankton density.

XI. Net plankton vs. nine abiotic variables (x_1 - x_9)

$$Y = 2683.1735 - 6.9132 (x_1) + 0.3501 (x_2) - 8.6301 (x_3) - 1.3253 (x_4) + 240.9658 (x_5) + 14.4173 (x_6) - 0.7340 (x_7) - 5.5902 (x_8) - 6.6362 (x_9)$$

$$R^2 = 0.8069$$

The stated nine abiotic factors accounted for 80% of the variations in the net plankton density.

XII. Net plankton vs. eight abiotic variables (x_1 - x_8)

$$Y = 2542.0039 + 5.4834 (x_1) - 12.8831 (x_2) + 0.4962 (x_3) - 8.9826 (x_4) - 3.0498 (x_5) - 217.5035 (x_6) + 8.7963 (x_7) - 0.3176 (x_8)$$

$$R^2 = 0.7798$$

The stated eight abiotic factors accounted for 77% of variations in the net plankton density.

XIII. Net plankton vs. seven abiotic variables (x_1 - x_7)

$$Y = 2754.1580 + 8.1934 (x_1) - 13.0181 (x_2) + 0.4468 (x_3) - 8.6626 (x_4) - 3.9922 (x_5) - 266.1707 (x_6) + 8.6797 (x_7)$$

$$R^2 = 0.7627$$

The stated seven abiotic factors accounted for 76% of the variations of the net plankton density.

XIV. Net plankton vs. six abiotic variables (x_1 - x_6)

$$Y = 2640.7712 + 8.5120 (x_1) - 14.0650 (x_2) + 0.5043 (x_3) - 8.2954 (x_4) - 4.0356 (x_5) - 254.1741 (x_6)$$

$$R^2 = 0.7571$$

The stated six abiotic factors accounted for 75% of the variations of the net plankton.

XV. Net plankton vs. five abiotic variables (x_1 - x_5)

$$Y = 2621.2457 + 11.6252 (x_1) - 17.0027 (x_2) + 0.4709 (x_3) - 8.2030 (x_4) - 3.9825 (x_5)$$

$$R^2 = 0.7494$$

The stated five abiotic factors alone accounted for 74% of the variations of the net plankton density.

XVI. Net plankton vs. four abiotic variables (x_1 - x_4)

$$Y = 972.8792 + 1.4772 (x_1) - 13.1206 (x_2) + 0.6710 (x_3) - 5.9063 (x_4)$$

$$R^2 = 0.627$$

The cumulative effect of above four factors was up to 62% on the net plankton density.

XVII. Net plankton vs. three abiotic variables (x_1 - x_3)

$$Y = 807.8699 + 5.6999 (x_1) - 11.4422 (x_2) + 0.5709 (x_3)$$

$$R^2 = 0.5479$$

The stated three abiotic factors alone accounted for 54% of variations in the net plankton density.

SITE 3 (PADDY-FIELD)

Net plankton (Y) vs. 19 abiotic factors (x_1 - x_{19}): cumulative

The multiple regression value between net plankton (Y) with nineteen abiotic factors at this site i.e., water temperature (x_1), rainfall (x_2), specific conductivity (x_3), pH (x_4), dissolved oxygen (x_5), free CO₂ (x_6), total alkalinity (x_7), total hardness (x_8), calcium (x_9), magnesium (x_{10}), sodium (x_{11}), potassium (x_{12}), chloride (x_{13}), sulphate (x_{14}), phosphate (x_{15}), nitrate (x_{16}), silicate (x_{17}), dissolved organic matter (x_{18}) and total dissolved solids (x_{19}) was represented by the following regression equation:

$$Y = -1788.7186 - 18.7563 (x_1) - 17.8166 (x_2) - 0.5432 (x_3) - 9.3711 (x_4) + 440.3056 (x_5) - 15.4878 (x_6) + 3.6363 (x_7) + 19.1336 (x_8) + 1.3238 (x_9) - 3.9850 (x_{10}) - 12.5645(x_{11}) +$$

$$0.5325 (x_{12}) - 83.9067 (x_{13}) + 1019.7315 (x_{14}) + 712.9834 (x_{15}) + 8.3548 (x_{16}) - 39.2127 (x_{17}) - 264.0436 (x_{18}) - 21.2200 (x_{19})$$

$$R^2 = 0.8521$$

Therefore, the stated nineteen variables accounted for 85% of the variations in net plankton densities at this study site. However, step-wise regression indicated the following:

I. Net plankton vs. eighteen abiotic variables (x_1 - x_{18})

$$Y = -1187.0591 - 25.4246 (x_1) - 9.5043 (x_2) - 0.5908 (x_3) - 9.7155 (x_4) + 348.7530 (x_5) - 20.8034 (x_6) + 2.3562 (x_7) + 18.5716 (x_8) + 0.4293 (x_9) - 14.6387 (x_{10}) - 23.7999 (x_{11}) + 15.1836 (x_{12}) - 82.2523 (x_{13}) + 211.4558 (x_{14}) + 755.5917 (x_{15}) + 8.4583 (x_{16}) - 35.9995 (x_{17}) - 18.7040 (x_{18})$$

$$R^2 = 0.8494$$

Therefore eighteen abiotic factors accounted for 84% of net plankton density variations.

II. Net plankton vs. seventeen abiotic variables (x_1 - x_{17})

$$Y = -1747.2573 - 26.8269 (x_1) - 16.0522 (x_2) - 0.7842 (x_3) - 9.7487 (x_4) + 436.7307 (x_5) - 43.8476 (x_6) - 1.1053 (x_7) + 19.8354 (x_8) + 7.1070 (x_9) - 13.9760 (x_{10}) - 29.4306 (x_{11}) + 20.3784 (x_{12}) + 10.6861 (x_{13}) - 935.3455 (x_{14}) + 479.8716 (x_{15}) + 8.0129 (x_{16}) - 6.2420 (x_{17})$$

$$R^2 = 0.8089$$

Above seventeen variables accounted for 80% of the variation in the net plankton density.

III. Net plankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y = 504.6391 - 6.1245 (x_1) - 13.0903 (x_2) + 0.1030 (x_3) - 1.5976 (x_4) + 6.2256 (x_5) + 1.8446 (x_6) - 0.7422 (x_7) + 7.9191 (x_8) - 4.2954 (x_9) - 15.8822 (x_{10}) - 17.9825 (x_{11}) + 11.6888 (x_{12}) + 13.6014 (x_{13}) + 1136.0754 (x_{14}) - 67.0855 (x_{15}) + 35.1320 (x_{16})$$

$$R^2 = 0.6433$$

Therefore, the impact of sixteen factors on the net plankton density was up to 64%.

V. Net plankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y = 1660.6148 - 14.5771(x_1) + 6.4894 (x_2) + 0.1300 (x_3) - 1.0623 (x_4) - 177.2011 (x_5) + 3.3062 (x_6) - 0.8887 (x_7) + 1.4030 (x_8) + 449.8728 (x_9) - 1870.7848 (x_{10}) - 15.6360 (x_{11}) - 26.7825 (x_{12}) + 40.0944 (x_{13}) - 17.5562 (x_{14}) + 1296.9949 (x_{15})$$

$$R^2 = 0.7269$$

The stated fifteen variables had higher cumulative effect on the density of net plankton than the above step as these accounted for 72% of the variations.

VI. Net plankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y = 1997.8569 - 22.1107 (x_1) + 12.6018 (x_2) + 0.1658 (x_3) - 1.9331 (x_4) - 204.4458 (x_5) + 3.5541 (x_6) - 2.9277 (x_7) + 0.5677 (x_8) + 429.5731 (x_9) - 1783.7384 (x_{10}) - 16.8827 (x_{11}) - 25.3522 (x_{12}) + 22.8462 (x_{13}) - 2.3505 (x_{14})$$

$$R^2 = 0.713$$

This step indicated that fourteen variables accounted for 71% of the variations.

VII. Net plankton vs. thirteen abiotic variables (x_1 - x_{13})

$$Y = 1972.5926 - 21.7747 (x_1) + 12.1162 (x_2) + 0.1566 (x_3) - 1.9684 (x_4) - 200.8781 (x_5) + 3.3003 (x_6) - 3.0006 (x_7) + 0.6974 (x_8) + 426.6588 (x_9) - 1771.2361 (x_{10}) - 16.6991 (x_{11}) - 25.4415 (x_{12}) + 22.4904 (x_{13})$$

$$R^2 = 0.713$$

The above thirteen abiotic factors also accounted for 71% of variations in the net plankton density.

VIII. Net plankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y = 1736.1905 - 25.8363 (x_1) + 12.7940 (x_2) + 0.2143 (x_3) - 2.7062 (x_4) - 149.9750 (x_5) + 7.7671 (x_6) - 1.5132 (x_7) + 1.2894 (x_8) + 372.9463 (x_9) - 1540.0606 (x_{10}) - 17.5547 (x_{11}) - 24.2263 (x_{12})$$

$$R^2 = 0.7024$$

The above twelve factors as a whole accounted for 70% of the variations in the net plankton density.

IX. Net plankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y = 1004.9644 - 15.1010 (x_1) - 0.4347 (x_2) + 0.2046 (x_3) - 1.6926 (x_4) - 53.8879 (x_5) + 3.3303 (x_6) - 0.1359 (x_7) + 3.0259 (x_8) + 301.5282 (x_9) - 1247.8924 (x_{10}) - 13.6496 (x_{11})$$

$$R^2 = 0.6512$$

The above eleven factors as a whole accounted for 65% of the variations in the net plankton.

X. Net plankton vs. ten abiotic variables (x_1 - x_{10})

$$Y = 1079.2387 - 16.8922 (x_1) + 4.4143 (x_2) + 0.1541 (x_3) - 1.6803 (x_4) - 75.9119 (x_5) + 6.4210 (x_6) + 3.8148 (x_7) + 2.8097 (x_8) + 317.2608 (x_9) - 1325.8930 (x_{10})$$

$$R^2 = 0.6412$$

The above ten abiotic factors had an impact of 64% on the net plankton density variations.

XI. Net plankton vs. nine abiotic variables (x_1 - x_9)

$$Y = 587.8428 - 11.9954 (x_1) - 5.7389 (x_2) + 0.1453 (x_3) - 1.5620 (x_4) - 0.0075 (x_5) + 3.2930 (x_6) + 4.0544 (x_7) + 6.4431 (x_8) - 3.4388 (x_9)$$

$$R^2 = 0.5835$$

The cumulative effect of the remaining nine variables explained for 58% of the net plankton variations.

XII. Net plankton vs. eight abiotic variables (x_1 - x_8)

$$Y = 800.5646 - 18.4385 (x_1) + 1.8828 (x_2) + 0.1408 (x_3) - 2.0112 (x_4) - 29.9443 (x_5) + 4.3221 (x_6) + 1.6608 (x_7) + 5.4593 (x_8)$$

$$R^2 = 0.5794$$

The stated eight abiotic factors accounted for 57% of the variations in the net plankton density.

XIII. Net plankton vs. seven abiotic variables (x_1 - x_7)

$$Y = 371.4880 - 15.5458 (x_1) - 4.4643 (x_2) + 0.1001 (x_3) - 2.5112 (x_4) + 39.3177 (x_5) + 1.3741 (x_6) + 1.1487 (x_7)$$

$$R^2 = 0.5665$$

The stated seven abiotic factors accounted for 56% of variations in the net plankton density.

XIV. Net plankton vs. six abiotic variables (x_1 - x_6)

$$Y = 865.8537 - 17.3160 (x_1) - 1.1707 (x_2) + 0.2034 (x_3) - 2.2093 (x_4) - 23.6908 (x_5) + 2.4140 (x_6)$$

$$R^2 = 0.5406$$

The stated six abiotic factors accounted for 54% of the variations in net plankton density.

XV. Net plankton vs. five abiotic variables (x_1 - x_5)

$$Y = 863.9650 - 18.9366 (x_1) + 0.3817 (x_2) + 0.2214 (x_3) - 2.2214 (x_4) - 20.8368 (x_5)$$

$$R^2 = 0.537$$

The stated five abiotic factors alone accounted for 53% of variations of the net plankton density at this study site.

XVI. Net plankton vs. four abiotic variables (x_1 - x_4)

$$Y = 893.8942 - 18.8445 (x_1) + 0.0499 (x_2) + 0.2094 (x_3) - 2.2552 (x_4)$$

$$R^2 = 0.5359$$

The above four abiotic factors exerted cumulative impact of 53% on the net plankton density.

XVII. Net plankton vs. three abiotic variables (x_1 - x_3)

$$Y = 758.4789 - 20.0625 (x_1) + 0.6850 (x_2) + 0.2239 (x_3) - 2.2814 (x_4)$$

$$R^2 = 0.5346$$

The stated three abiotic factors alone accounted for 53% of variations in the net plankton density at this site.

XVIII. Net plankton vs. three abiotic variables (x_1 - x_2)

$$Y = 651.5504 - 7.7685 (x_1) - 12.8530 (x_2)$$

$$R^2 = 0.5015$$

Therefore the stated two variables accounted for 50% of the variations in net plankton density.

SITE 1 (POND)

Phytoplankton (Y_P) vs. 20 abiotic factors (x_1 - x_{20}): cumulative

The multiple correlation of phytoplankton (Y_P) with twenty abiotic variables (x_1 - x_{20}) at Site 1 was computed and in turn, indicated the following regression equation:

$$Y_P = 5473.9520 - 13.2984 (x_1) - 19.1950 (x_2) - 0.5413 (x_3) - 10.7450 (x_4) + 11.7278 (x_5) - 275.2415 (x_6) - 41.0738 (x_7) + 1.7617 (x_8) - 18.2500 (x_9) + 2.6377 (x_{10}) - 95.5291 (x_{11}) + 2.4346 (x_{12}) - 37.1174 (x_{13}) - 5.2443 (x_{14}) + 408.1048 (x_{15}) - 3334.2900 (x_{16}) + 291.8195 (x_{17}) - 2.8419 (x_{18}) - 9.6139 (x_{19}) + 328.7811 (x_{20})$$

$$R^2 = 0.9264$$

Therefore, the stated twenty variables accounted for 92% of the variations of phytoplankton densities at this study site. However, step-wise regression indicated the following regressions.

I. Phytoplankton vs. nineteen abiotic variables (x_1 - x_{19})

$$Y_P = 621.9974 - 2.2174 (x_1) - 19.5397 (x_2) + 1.0033 (x_3) - 1.4875 (x_4) + 0.9446 (x_5) - 3.2389 (x_6) + 35.2188 (x_7) + 12.3568 (x_8) - 11.0510 (x_9) + 31.1970 (x_{10}) + 38.3354 (x_{11}) - 13.4427 (x_{12}) - 32.7114 (x_{13}) - 43.0866 (x_{14}) - 130.4849 (x_{15}) + 957.6447 (x_{16}) - 299.9335 (x_{17}) - 0.8031 (x_{18}) + 51.5912 (x_{19})$$

$$R^2 = 0.8288$$

The stated nineteen variables accounted for 82% of the variations in phytoplankton densities. However, the step-wise regression indicated the following:

II. Phytoplankton vs. eighteen abiotic variables (x_1 - x_{18})

$$Y_P = 2808.1504 - 9.4472 (x_1) - 6.4689 (x_2) - 0.3067 (x_3) - 6.5615 (x_4) - 3.4597 (x_5) + 122.6018 (x_6) - 1.0349 (x_7) + 5.4355 (x_8) - 17.2706 (x_9) + 7.1308 (x_{10}) + 49.9819 (x_{11}) -$$

$$4.7325 (x_{12}) - 22.3334 (x_{13}) - 15.9664 (x_{14}) - 211.5243 (x_{15}) + 2623.7198 (x_{16}) - 72.1579 (x_{17}) - 1.9121 (x_{18})$$

$$R^2 = 0.7894$$

These factors accounted for 78% of variation in the density of phytoplankton.

III. Phytoplankton vs. seventeen abiotic variables (x_1 - x_{17})

$$Y_p = 2808.1504 - 9.4472 (X_1) - 6.4689 (X_2) - 0.3067 (X_3) - 6.5615 (X_4) - 3.4597 (X_5) + 122.6018 (X_6) - 1.0349 (X_7) + 5.4355 (X_8) - 17.2706 (X_9) + 7.1308 (X_{10}) + 49.9819 (X_{11}) - 4.7325 (X_{12}) - 22.3334 (X_{13}) - 15.9664 (X_{14}) - 211.5243 (X_{15}) + 2623.7198 (X_{16}) - 2.1579 (X_{17})$$

$$R^2 = 0.7894$$

Above seventeen variables accounted for 78% of the variation in the phytoplankton density.

IV. Phytoplankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y_p = 1452.4493 - 16.7647 (x_1) + 6.9371 (x_2) - 0.0178 (x_3) - 3.6763 (x_4) - 1.7841(x_5) - 53.3375 (x_6) + 17.1592 (x_7) + 7.5422 (x_8) - 12.6093 (x_9) + 16.5968 (x_{10}) - 39.4779 (x_{11}) - 13.0419 (x_{12}) - 19.9726 (x_{13}) - 24.1367 (x_{14}) - 155.0492 (x_{15}) - 1387.6982 (x_{16})$$

$$R^2 = 0.7585$$

The stated sixteen variables accounted for 75% of the variations of phytoplankton densities.

V. Phytoplankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y_p = 495.8821 - 16.4687(x_1) + 15.9676 (x_2) + 0.0529 (x_3) - 2.4064 (x_4) + 1.4971 (x_5) + 13.2523 (x_6) + 28.5903 (x_7) + 7.3710 (x_8) - 11.9918 (x_9) + 22.3143 (x_{10}) - 47.7165 (x_{11}) - 12.2163 (x_{12}) - 14.9677 (x_{13}) - 25.8932 (x_{14}) + 124.8254 (x_{15})$$

$$R^2 = 0.743$$

The above fifteen variables accounted for 74% of the variations in density of phytoplankton.

VI. Phytoplankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y_p = 353.6921 - 9.6913 (x_1) + 13.6096 (x_2) - 0.1891 (x_3) - 2.6252 (x_4) + 0.8761 (x_5) + 19.9142 (x_6) + 33.3191 (x_7) + 7.3878 (x_8) - 12.9158 (x_9) + 21.1536 (x_{10}) - 52.6163 (x_{11}) - 4.6206 (x_{12}) - 9.9158 (x_{13}) - 27.7078 (x_{14})$$

$$R^2 = 0.7289$$

The above mentioned fourteen factors accounted for 72% of the variations in the phytoplankton density.

VII. Phytoplankton vs. thirteen abiotic variables (x_1 - x_{13})

$$Y_p = 514.1059 - 4.0191 (x_1) + 5.7066 (x_2) - 0.4198 (x_3) - 4.3036 (x_4) - 2.6202 (x_5) + 15.2578 (x_6) + 22.0195 (x_7) + 1.1605 (x_8) - 8.3399 (x_9) + 14.1749 (x_{10}) - 7.5384 (x_{11}) + 1.4581 (x_{12}) - 6.5725 (x_{13})$$

$$R^2 = 0.6881$$

The above thirteen abiotic factors accounted for 68% of variations of the phytoplankton density.

VIII. Phytoplankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y_p = 514.1059 - 4.0191 (x_1) + 5.7066 (x_2) - 0.4198 (x_3) - 4.3036 (x_4) - 2.6202 (x_5) + 15.2578 (x_6) + 22.0195 (x_7) + 1.1605 (x_8) - 8.3399 (x_9) + 14.1749 (x_{10}) + 47.5384 (x_{11}) + 1.4581 (x_{12})$$

$$R^2 = 0.6881$$

The above twelve factors as a whole accounted for 68% of the variations of the phytoplankton density.

IX. Phytoplankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y_p = 578.7571 - 5.2419 (x_1) + 9.0607 (x_2) - 0.5051 (x_3) - 4.4651 (x_4) - 2.8305 (x_5) + 9.8915 (x_6) + 22.6639 (x_7) + 0.8336 (x_8) - 9.4237 (x_9) + 13.1126 (x_{10}) - 51.8103 (x_{11})$$

$$R^2 = 0.6865$$

Therefore, the above eleven variables also accounted for 68% of the variations in the phytoplankton density.

X. Phytoplankton vs. ten abiotic variables (x_1 - x_{10})

$$Y_p = 86.978 - 2.5934 (x_1) + 9.5253 (x_2) - 0.5454 (x_3) - 2.2240 (x_4) - 1.4611 (x_5) + 30.2367 (x_6) + 17.7511 (x_7) - 0.3160 (x_8) - 5.5147 (x_9) + 0.8264 (x_{10})$$

$$R^2 = 0.6167$$

Stated ten abiotic factors accounted for 61% of the variations of the phytoplankton density.

XI. Phytoplankton vs. nine abiotic variables (x_1 - x_9)

$$Y_p = 77.9714 - 2.8265 (x_1) + 10.0376 (x_2) - 0.5408 (x_3) - 2.1642 (x_4) - 0.8772 (x_5) + 27.8495 (x_6) + 19.2727 (x_7) - 0.2550 (x_8) - 5.4189 (x_9)$$

$$R^2 = 0.6151$$

The stated nine abiotic factors also accounted for 61% of the variations in the phytoplankton density.

XII. Phytoplankton vs. eight abiotic variables (x_1 - x_8)

$$Y_p = 147.8821 - 2.0862 (x_1) + 8.8116 (x_2) - 0.5451 (x_3) - 2.1612 (x_4) - 0.8825 (x_5) + 23.0311 (x_6) + 18.1844 (x_7) - 0.0712 (x_8)$$

$$R^2 = 0.6141$$

Above eight abiotic factors accounted for 61% of the variations in the phytoplankton density.

XIII. Phytoplankton vs. seven abiotic variables (x_1 - x_7)

$$Y_p = -14.0046 + 0.0369 (x_1) + 7.1158 (x_2) - 0.4574 (x_3) - 1.5674 (x_4) - 0.8438 (x_5) + 16.6957 (x_6) + 19.4313 (x_7)$$

$$R^2 = 0.5754$$

The stated seven abiotic factors accounted for 57% of the variations in phytoplankton density.

XIV. Phytoplankton vs. six abiotic variables (x_1 - x_6)

$$Y_p = -90.5371 - 0.9050 (x_1) + 6.6756(x_2) - 0.3660 (x_3) - 0.9995 (x_4) - 0.6611 (x_5) + 18.9791 (x_6)$$

$$R^2 = 0.5657$$

The stated six abiotic factors accounted for 56% of the variations of the phytoplankton density.

XV. Phytoplankton vs. five abiotic variables (x_1 - x_5)

$$Y_p = 207.4607 + 2.2036 (x_1) - 5.0180 (x_2) - 0.4813 (x_3) - 2.0636 (x_4) - 2.0478 (x_5)$$

$$R^2 = 0.5084$$

Therefore, the above five abiotic factors alone accounted for 50% of the variations in the phytoplankton density at this site.

SITE 2 (PEAT BOG)

Phytoplankton (Y_p) vs. 20 abiotic factors (x_1 - x_{20}): cumulative

The multiple correlation of phytoplankton (Y_p) with twenty abiotic variables (x_1 - x_{20}) at Site 2 was computed which indicated the following regression equation:

$$Y_p = 2758.4382 + 1.9768 (x_1) - 2.5190 (x_2) + 0.0202 (x_3) - 7.9215 (x_4) - 4.4316 (x_5) - 247.8123 (x_6) + 26.9502 (x_7) - 3.0626 (x_8) - 8.5092 (x_9) - 14.2380 (x_{10}) - 30.7279 (x_{11}) + 41.7114 (x_{12}) + 4.0698 (x_{13}) + 21.5754 (x_{14}) + 27.0988 (x_{15}) + 15.5655 (x_{16}) - 283.8789 (x_{17}) - 4.8790 (x_{19}) + 10.7843 (x_{20}) - 256.7150 (x_{21})$$

$$R^2 = 0.9526$$

Therefore, the stated twenty variables accounted for 95% of the variations in phytoplankton densities at this site. However, step-wise regression indicated the following regressions.

I. Phytoplankton vs. nineteen abiotic variables (x_1 - x_{19})

$$Y_P = 2569.9307 + 2.5716 (x_1) - 7.3643 (x_2) + 0.4881 (x_3) - 8.0284 (x_4) - 6.0771 (x_5) - 261.9142 (x_6) + 27.8255 (x_7) - 2.8056 (x_8) - 7.8302 (x_9) - 13.3613 (x_{10}) - 5.9765 (x_{11}) + 50.6513 (x_{12}) + 2.7337 (x_{13}) + 20.6173 (x_{14}) + 14.1120 (x_{15}) - 52.0804 (x_{16}) + 71.4562 (x_{17}) + 1.2711 (x_{18}) + 17.8468 (x_{20})$$

$$R^2 = 0.9419$$

The stated nineteen variables accounted for 94% of the variations in phytoplankton densities. The step-wise regression showed the following:

II. Phytoplankton vs. eighteen abiotic variables (x_1 - x_{18})

$$Y_P = 2659.3371 + 11.5128 (x_1) - 12.1900 (x_2) - 0.0832 (x_3) - 10.8572 (x_4) - 7.5497 (x_5) - 243.5027 (x_6) + 26.1163 (x_7) - 0.8778 (x_8) - 9.2656 (x_9) + 0.0973 (x_{10}) - 26.7830 (x_{11}) + 45.5152 (x_{12}) + 14.7156 (x_{13}) + 2.1922 (x_{14}) + 7.0888 (x_{15}) + 220.1248 (x_{16}) + 941.2245 (x_{17}) + 12.9382 (x_{18})$$

$$R^2 = 0.9319$$

These factors accounted for 93% of variation in the density of phytoplankton

III. Phytoplankton vs. seventeen abiotic variables (x_1 - x_{17})

$$Y_P = 2585.1831 + 6.2298 (x_1) - 4.9345 (x_2) - 0.1583 (x_3) - 9.5204 (x_4) - 5.6648 (x_5) - 215.9272 (x_6) + 27.2611 (x_7) - 2.3822 (x_8) - 6.9747 (x_9) - 7.9621 (x_{10}) - 26.6593 (x_{11}) + 39.2543 (x_{12}) + 12.8658 (x_{13}) - 9.1964 (x_{14}) - 9.6946 (x_{15}) + 555.6403 (x_{16}) + 503.7352 (x_{17})$$

$$R^2 = 0.925$$

Above seventeen variables accounted for 92% of the variation in the phytoplankton density.

IV. Phytoplankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y_P = 2438.9696 + 6.8478 (x_1) - 2.9911 (x_2) - 0.0660 (x_3) - 9.0665 (x_4) - 4.4172 (x_5) - 207.7215 (x_6) + 23.7236 (x_7) - 2.9208 (x_8) - 6.2337 (x_9) - 10.0839 (x_{10}) - 28.9026 (x_{11}) + 39.3391 (x_{12}) + 9.7399 (x_{13}) - 5.8797 (x_{14}) + 12.5882 (x_{15}) + 443.8510 (x_{16})$$

$$R^2 = 0.923$$

The stated sixteen variables also accounted for 92% of the variations of phytoplankton densities.

V. Phytoplankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y_p = 2426.1503 + 8.8808 (x_1) - 6.6881 (x_2) + 0.3009 (x_3) - 8.5580 (x_4) - 4.2306 (x_5) - 226.3361 (x_6) + 17.7117 (x_7) - 2.5789 (x_8) - 6.1085 (x_9) - 12.2653 (x_{10}) - 23.3515 (x_{11}) + 38.2030 (x_{12}) + 8.7453 (x_{13}) + 1.7284 (x_{14}) + 43.2219 (x_{15})$$

$$R^2 = 0.921$$

Therefore, above fifteen variables also accounted for 92% of variations in density of phytoplankton.

VI. Phytoplankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y_p = 2405.5140 + 6.6513 (x_1) - 4.5467 (x_2) + 0.1832 (x_3) - 8.2128 (x_4) - 3.5837 (x_5) - 214.6720 (x_6) + 26.6183 (x_7) - 1.9183 (x_8) - 7.2386 (x_9) - 10.5583 (x_{10}) - 39.5986 (x_{11}) + 41.2668 (x_{12}) + 13.9642 (x_{13}) + 1.2118 (x_{14})$$

$$R^2 = 0.9128$$

The above mentioned fourteen factors accounted for 91% of variations in phytoplankton density.

VII. Phytoplankton vs. thirteen abiotic variables (x_1 - x_{13})

$$Y_p = 2417.1164 + 6.6419 (x_1) - 4.3773 (x_2) + 0.1681 (x_3) - 8.2227 (x_4) - 3.6425 (x_5) - 215.4085 (x_6) + 26.5374 (x_7) - 1.9231 (x_8) - 7.2150 (x_9) - 10.3826 (x_{10}) - 39.7429 (x_{11}) + 41.2240 (x_{12}) + 13.9686 (x_{13})$$

$$R^2 = 0.9128$$

The above thirteen abiotic factors also accounted for 91% of variations of phytoplankton density.

VIII. Phytoplankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y_p = 2585.4281 + 4.0938 (x_1) - 4.2746 (x_2) + 0.3497 (x_3) - 8.0093 (x_4) - 1.5692 (x_5) - 242.3583 (x_6) + 31.7969 (x_7) - 2.7366 (x_8) - 8.8057 (x_9) - 10.2867 (x_{10}) - 32.9689 (x_{11}) + 42.1046 (x_{12})$$

$$R^2 = 0.8989$$

The above twelve factors as a whole accounted for 89% of the variations of the phytoplankton density.

IX. Phytoplankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y_p = 2665.2047 + 5.9378 (x_1) - 8.6149 (x_2) + 0.2916 (x_3) - 8.6248 (x_4) - 0.6477 (x_5) - 237.8907 (x_6) + 16.3854 (x_7) - 1.3761 (x_8) - 7.0308 (x_9) - 6.9604 (x_{10}) - 14.8015 (x_{11})$$

$$R^2 = 0.8315$$

Therefore the remaining eleven abiotic parameters explained for 83% of phytoplankton density variations.

X. Phytoplankton vs. ten abiotic variables (x_1 - x_{10})

$$Y_p = 2584.2142 + 6.3052 (x_1) - 9.7387 (x_2) + 0.3682 (x_3) - 8.5123 (x_4) - 0.8739 (x_5) - 228.7455 (x_6) + 15.8753 (x_7) - 1.3488 (x_8) - 6.4595 (x_9) - 10.8141 (x_{10})$$

$$R^2 = 0.8302$$

The above ten variables also accounted for 83% of density variations.

XI. Phytoplankton vs. nine abiotic variables (x_1 - x_9)

$$Y_p = 2631.0733 + 5.4341 (x_1) - 7.3226 (x_2) + 0.2246 (x_3) - 8.5744 (x_4) - 0.6985 (x_5) - 232.1935 (x_6) + 15.6397 (x_7) - 1.1056 (x_8) - 6.8475 (x_9)$$

$$R^2 = 0.8273$$

The stated nine abiotic factors also accounted for 82% of the variations of the phytoplankton density.

XII. Phytoplankton vs. eight abiotic variables (x_1 - x_8)

$$Y_p = 2411.1307 + 7.1494 (x_1) - 16.6238 (x_2) + 0.4524 (x_3) - 9.1237 (x_4) - 3.3853 (x_5) - 195.6392 (x_6) + 6.8821 (x_7) - 0.4569 (x_8)$$

$$R^2 = 0.7614$$

The stated eight abiotic factors accounted for 76% of the variations in the phytoplankton density.

XIII. Phytoplankton vs. seven abiotic variables (x_1 - x_7)

$$Y_p = 2622.9180 + 9.8547 (x_1) - 16.7586 (x_2) + 0.4030 (x_3) - 8.8042 (x_4) - 4.3260 (x_5) - 244.2223 (x_6) + 6.7657 (x_7)$$

$$R^2 = 0.7441$$

The stated seven abiotic factors accounted for 74% of the variations of the phytoplankton density.

XIV. Phytoplankton vs. six abiotic variables (x_1 - x_6)

$$Y_p = 2493.7068 + 10.2178 (x_1) - 17.9516 (x_2) + 0.4685 (x_3) - 8.3858 (x_4) - 4.3754 (x_5) - 230.5514 (x_6)$$

The stated six abiotic factors accounted for 73% of the variations of the phytoplankton density.

XV. Phytoplankton vs. five abiotic variables (x_1 - x_5)

$$Y_p = 2478.8837 + 12.5813 (x_1) - 20.1818 (x_2) + 0.4432 (x_3) - 8.3157 (x_4) - 4.3351 (x_5)$$

$$R^2 = 0.7323$$

The stated five abiotic factors alone accounted for 73% of the variations of the phytoplankton density.

XVI. Phytoplankton vs. four abiotic variables (x_1 - x_4)

$$Y_p = 978.5191 + 3.3444 (x_1) - 16.6482 (x_2) + 0.6253 (x_3) - 6.2252 (x_4)$$

$$R^2 = 0.6306$$

The stated four abiotic factors alone accounted for 63% of the variations of the phytoplankton density.

XVII. Phytoplankton vs. three abiotic variables (x_1 - x_3)

$$Y_p = 792.0720 + 8.1157 (x_1) - 14.7518 (x_2) + 0.5122 (x_3)$$

$$R^2 = 0.5291$$

Therefore the stated three abiotic factors accounted for 52% of the variations of the phytoplankton density at this site.

SITE 3 (PADDY-FIELD)

Phytoplankton (Y_p) vs. 19 abiotic factors (x_1 - x_{20}): cumulative

The multiple correlation of phytoplankton (Y_p) with nineteen abiotic variables (x_1 - x_{19}) at Site 3 was computed which indicated the following regression equation:

$$Y_p = -1492.9579 - 22.8211 (x_1) - 12.5815 (x_2) - 0.5790 (x_3) - 8.9811 (x_4) + 390.0307 (x_5) - 19.5564 (x_6) + 1.8984 (x_7) + 16.9361 (x_8) - 0.0897 (x_9) - 22.9570 (x_{10}) - 7.2626 (x_{11}) - 13.4925 (x_{12}) + 4.1215 (x_{13}) - 86.0600 (x_{14}) + 1108.6588 (x_{15}) + 737.6252 (x_{16}) + 7.3297 (x_{17}) - 35.3073 (x_{18}) - 119.6819 (x_{19})$$

$$R^2 = 0.8438$$

Therefore, the stated nineteen variables accounted for 84% of the variations in phytoplankton densities at this site. However, step-wise regression indicated the following regressions.

I. Phytoplankton vs. eighteen abiotic variables (x_1 - x_{18})

$$Y_p = -1220.2463 - 25.8437 (x_1) - 8.8138 (x_2) - 0.6006 (x_3) - 9.1372 (x_4) + 348.5331 (x_5) - 21.9658 (x_6) + 1.3182 (x_7) + 16.6813 (x_8) - 0.4952 (x_9) - 21.3610 (x_{10}) - 12.0915 (x_{11}) - 18.5852 (x_{12}) + 10.7623 (x_{13}) - 85.3101 (x_{14}) + 742.2952 (x_{15}) + 756.9381 (x_{16}) + 7.3766 (x_{17}) - 33.8509 (x_{18})$$

$$R^2 = 0.8433$$

Therefore stated eighteen variables also accounted for 84% of the variations in phytoplankton densities as in the former step.

II. Phytoplankton vs. seventeen abiotic variables (x_1 - x_{17})

$$Y_P = -1747.0094 - 27.1622 (x_1) - 14.9709 (x_2) - 0.7825 (x_3) - 9.1685 (x_4) + 431.2598 (x_5) - 43.6346 (x_6) - 1.9367 (x_7) + 17.8697 (x_8) + 5.7840 (x_9) - 9.3550 (x_{10}) - 11.4684 (x_{11}) - 23.8798 (x_{12}) + 15.6470 (x_{13}) + 2.0814 (x_{14}) - 336.0601 (x_{15}) + 497.6742 (x_{16}) + 6.9578 (x_{17})$$

$$R^2 = 0.808$$

These seventeen factors accounted for 80% of variation in the density of phytoplankton

III. Phytoplankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y_P = 210.7417 - 9.1302 (x_1) - 12.3809 (x_2) - 0.0112 (x_3) - 2.0699 (x_4) + 56.6480 (x_5) - 3.8452 (x_6) - 1.5823 (x_7) + 7.5239 (x_8) + 31.5990 (x_9) - 1.0443 (x_{10}) - 13.0382 (x_{11}) - 13.8609 (x_{12}) + 8.2476 (x_{13}) + 4.4067 (x_{14}) + 1470.5067 (x_{15}) + 20.2179 (x_{16})$$

$$R^2 = 0.6848$$

Above sixteen variables accounted for 68% of the variation in the phytoplankton density.

IV. Phytoplankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y_P = 1290.2785 - 14.5834 (x_1) + 4.9914 (x_2) + 0.0422 (x_3) - 0.9832 (x_4) - 126.8899 (x_5) + 0.8027 (x_6) - 0.6429 (x_7) + 1.6431 (x_8) + 424.5023 (x_9) - 1773.8215 (x_{10}) - 0.9517 (x_{11}) - 9.5179 (x_{12}) + 7.8483 (x_{13}) - 9.6068 (x_{14}) + 861.7979 (x_{15})$$

$$R^2 = 0.7585$$

Therefore above fifteen factors explained for 75% phytoplankton density variations.

V. Phytoplankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y_P = 1774.3796 - 25.3975 (x_1) + 13.7657 (x_2) + 0.0935 (x_3) - 2.2332 (x_4) - 165.9989 (x_5) + 1.1585 (x_6) - 3.5698 (x_7) + 0.4441 (x_8) + 395.3627 (x_9) - 1648.8689 (x_{10}) - 12.7413 (x_{11}) - 17.4648 (x_{12}) + 13.0890 (x_{13}) - 7.7796 (x_{14})$$

$$R^2 = 0.7302$$

The above fourteen variables accounted for 73% of the variation in the density of phytoplankton.

VI. Phytoplankton vs. thirteen abiotic variables (x_1 - x_{13})

$$Y_P = 1690.7608 - 24.2857 (x_1) + 12.1583 (x_2) + 0.0633 (x_3) - 2.3501 (x_4) - 154.1907 (x_5) + 0.3186 (x_6) - 3.8111 (x_7) + 0.8736 (x_8) + 385.7169 (x_9) - 1607.4896 (x_{10}) - 12.1335 (x_{11}) - 17.7606 (x_{12}) + 11.9113 (x_{13})$$

$$R^2 = 0.7298$$

The above thirteen factors accounted for 72% of the variations in the phytoplankton density.

VII. Phytoplankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y_p = 1565.5582 - 26.4367 (x_1) + 12.5173 (x_2) + 0.0939 (x_3) - 2.7409 (x_4) - 127.2315 (x_5) + 2.6843 (x_6) - 3.0234 (x_7) + 1.1871 (x_8) + 357.2698 (x_9) - 1485.0550 (x_{10}) - 12.5867 (x_{11}) - 17.1170 (x_{12})$$

$$R^2 = 0.7269$$

The above twelve parameters also accounted for 72% of density variations.

VIII. Phytoplankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y_p = 1048.9147 - 18.8518 (x_1) + 3.1707 (x_2) + 0.0870 (x_3) - 2.0247 (x_4) - 59.3418 (x_5) + 0.4506 (x_6) - 2.0502 (x_7) + 2.4140 (x_8) + 306.8099 (x_9) - 1278.6253 (x_{10}) - 9.8276 (x_{11})$$

$$R^2 = 0.7017$$

The above eleven factors accounted for 70% of the density variations of phytoplankton.

IX. Phytoplankton vs. ten abiotic variables (x_1 - x_{10})

$$Y_p = 1102.3914 - 20.1414 (x_1) + 6.6619 (x_2) + 0.0507 (x_3) - 2.0158 (x_4) - 75.1988 (x_5) + 1.7747 (x_6) + 0.7942 (x_7) + 2.2584 (x_8) + 318.1372 (x_9) - 1334.7849 (x_{10})$$

$$R^2 = 0.6965$$

Above ten abiotic factors also accounted for 69% of density variations.

X. Phytoplankton vs. nine abiotic variables (x_1 - x_9)

$$Y_p = 607.7000 - 15.2118 (x_1) - 3.5595 (x_2) + 0.0418 (x_3) - 1.8967 (x_4) + 1.2147 (x_5) - 1.3743 (x_6) + 1.0354 (x_7) + 5.9161 (x_8) - 4.7132 (x_9)$$

$$R^2 = 0.6388$$

The cumulative effect of the above nine variables on the phytoplankton density was 63%.

XI. Phytoplankton vs. eight abiotic variables (x_1 - x_8)

$$Y_p = 625.4504 - 15.7494 (x_1) - 2.9235 (x_2) + 0.0414 (x_3) - 1.9342 (x_4) - 1.2834 (x_5) - 1.2884 (x_6) + 0.8356 (x_7) + 5.8340 (x_8)$$

$$R^2 = 0.6387$$

The stated eight abiotic factors also accounted for 63% of the variations of the phytoplankton density.

XII. Phytoplankton vs. seven abiotic variables (x_1 - x_7)

$$Y_p = 153.5656 - 12.5682 (x_1) - 9.9038 (x_2) - 0.0034 (x_3) - 2.4841 (x_4) + 74.8887(x_5) - 4.5306 (x_6) + 0.2724 (x_7)$$

$$R^2 = 0.6233$$

Further seven abiotic parameters explained for 62% of density variations.

XIII. Phytoplankton vs. six abiotic variables (x_1 - x_6)

$$Y_p = 679.9642 - 14.4530 (x_1) - 6.3968 (x_2) + 0.1067 (x_3) - 2.1627 (x_4) + 7.7976 (x_5) - 3.4233 (x_6)$$

$$R^2 = 0.5944$$

The stated six abiotic factors accounted for 59% of the variations of the phytoplankton density.

XIV. Phytoplankton vs. five abiotic variables (x_1 - x_5)

$$Y_p = 678.7559 - 15.4898 (x_1) - 5.4036 (x_2) + 0.1181 (x_3) - 2.1704 (x_4) + 9.6234 (x_5)$$

$$R^2 = 0.5929$$

These five parameters accounted for 59% of the density variations.

XV. Phytoplankton vs. four abiotic variables (x_1 - x_4)

$$Y_p = 625.0857 - 15.6549 (x_1) - 4.8084 (x_2) + 0.1395 (x_3) - 2.1099 (x_4)$$

$$R^2 = 0.5895$$

The stated four abiotic factors alone accounted for 58% of the variations in phytoplankton density.

XVI. Phytoplankton vs. three abiotic variables (x_1 - x_3)

$$Y_p = 697.5062 - 15.0035(x_1) - 5.1481(x_2) + 0.1318(x_3) - 2.0959(x_4)$$

$$R^2 = 0.5891$$

The stated three abiotic factors also accounted for 58% of the variations of the phytoplankton density.

XVII. Phytoplankton vs. two abiotic variables (x_1 - x_2)

$$Y_p = 599.2724 - 3.7091(x_1) - 17.5853 (x_2)$$

$$R^2 = 0.5615$$

The stated two abiotic factors accounted for 56% of the variations in phytoplankton density at this site.

SITE 1 (POND)

Zooplankton (Y_z) vs. 20 abiotic (x_1 - x_{20}) factors: cumulative

The multiple correlation of zooplankton (Y_z) with twenty abiotic variables (x_1 - x_{20}) at Site 1 was computed and indicated the following regression equation:

$$Y_z = 4678.3903 + 5.4670 (x_1) - 61.8632 (x_2) - 0.3231 (x_3) - 4.8002 (x_4) - 6.6576 (x_5) \\ 496.4198 (x_6) - 54.1228 (x_7) + 4.1124 (x_8) + 21.6470 (x_9) - 1.9673 (x_{10}) + 11.7000 (x_{11}) + \\ 0.5599 (x_{12}) - 45.6569 (x_{13}) - 0.3141 (x_{14}) + 138.1055(x_{15}) + 2655.6540 (x_{16}) - 3424.7486 \\ (x_{17}) + 4.5771 (x_{18}) + 43.5817 (x_{19}) + 304.5158 (x_{20})$$

$$R^2 = 0.964$$

Therefore, the stated twenty variables accounted for 96% of the variations in zooplankton densities at this study site. However, step-wise regression indicated the following:

I. Zooplankton vs. nineteen abiotic variables (x_1 - x_{19})

$$Y_z = 9172.2531 - 4.7961 (x_1) - 61.5439 (x_2) - 1.7537 (x_3) - 13.374 (x_4) + 18.3947 (x_5) - \\ 748.3471 (x_6) - 124.7847 (x_7) - 5.7007 (x_8) + 14.9793 (x_9) + 28.4188 (x_{10}) - 41.27263 (x_{11}) + \\ 15.2654 (x_{12}) - 49.7377 (x_{13}) + 34.7353 (x_{14}) + 119.0250 (x_{15}) - 4856.8943 (x_{16}) - 2876.6691 \\ (x_{17}) + 2.6887 (x_{18}) - 13.1062 (x_{19})$$

$$R^2 = 0.9566$$

The stated nineteen variables accounted for 95% of the variations in zooplankton density.

II. Zooplankton vs. eighteen abiotic variables (x_1 - x_{18})

$$Y_z = 8616.8806 - 2.9594 (x_1) - 64.8644 (x_2) - 1.4209 (x_3) - 12.0854 (x_4) - 17.2758 (x_5) - \\ 718.0246 (x_6) - 115.5748 (x_7) - 3.9424 (x_8) + 16.5593 (x_9) + 22.305 (x_{10}) - 38.3139 (x_{11}) + \\ 13.0527 (x_{12}) - 52.3741 (x_{13}) + 27.8456 (x_{14}) + 98.4376 (x_{15}) - 4433.643 (x_{16}) - 2934.5334 \\ (x_{17}) + 2.9704 (x_{18})$$

$$R^2 = 0.9564$$

The eighteen factors also accounted for 95% of variations in the density of zooplankton.

III. Zooplankton vs. seventeen abiotic variables (x_1 - x_{17})

$$Y_z = 10989.3407 + 6.1029 (x_1) - 73.6522 (x_2) - 2.2581 (x_3) - 18.9085(x_4) + 20.0992 (x_5) - \\ 820.6828 (x_6) - 138.9339 (x_7) - 8.9098 (x_8) + 2.3130 (x_9) + 34.7257 (x_{10}) - 85.8541 (x_{11}) + \\ 26.9923 (x_{12}) - 38.8620 (x_{13}) + 34.8564 (x_{14}) + 225.5125 (x_{15}) - 5953.0617 (x_{16}) - \\ 3791.4405 (x_{17})$$

$$R^2 = 0.9516$$

Above seventeen variables also accounted for 95% of the variations in the zooplankton density.

IV. Zooplankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y_Z = 9633.3268 + 17.8376 (x_1) - 134.93354 (x_2) - 0.2810 (x_3) - 6.9920 (x_4) + 18.9774 (x_5) - 845.8488 (x_6) - 163.90466 (x_7) - 0.283384 (x_8) + 37.9718 (x_9) + 46.3561 (x_{10}) + 73.0823 (x_{11}) + 21.7432 (x_{12}) - 126.3144 (x_{13}) + 63.7793 (x_{14}) + 25.2479 (x_{15}) - 7993.0066 (x_{16})$$

$$R^2 = 0.9068$$

The stated sixteen variables accounted for 90% of the variations of zooplankton densities.

V. Zooplankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y_Z = 4123.5929 + 19.5425 (x_1) - 82.9189 (x_2) + 0.1258 (x_3) + 0.3226 (x_4) + 17.32406 (x_5) - 462.2981 (x_6) - 98.0623 (x_7) - 1.2692 (x_8) + 41.5285 (x_9) + 13.4241 (x_{10}) + 25.6289 (x_{11}) + 26.4981 (x_{12}) - 97.4864 (x_{13}) + 53.6620 (x_{15}) + 148.8381 (x_{15})$$

$$R^2 = 0.8614$$

The above fifteen variables accounted for 86% of the variation in zooplankton density.

VI. Zooplankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y_Z = 4293.1362 + 11.4614 (x_1) - 80.1073 (x_2) + 0.4143 (x_3) + 0.5836 (x_4) - 18.0645 (x_5) - 470.2415(x_6) - 103.7008 (x_7) - 1.2892 (x_8) + 42.6302 (x_9) - 12.0402 (x_{10}) + 31.4713 (x_{11}) + 17.4412 (x_{12}) - 103.5101 (x_{13}) + 55.8257 (x_{14})$$

$$R^2 = 0.8596$$

The above fourteen factors alone accounted for 85% of the density variations of zooplankton.

VII. Zooplankton vs. thirteen abiotic variables (X_1 - X_{13})

$$Y_Z = 3969.9342 + 0.0331(x_1) -64.1843 (x_2) + 0.8791 (x_3) + 3.9653 (x_4) - 14.5505 (x_5) - 460.8599 (x_6) - 80.9342 (x_7) + 11.257433 (x_8) + 33.4108 (x_9) + 2.0205 (x_{10}) + 21.2405 (x_{11}) + 5.1938 (x_{12}) - 110.2468 (x_{13})$$

$$R^2 = 0.845$$

The above thirteen abiotic factors accounted for 84% of variations in zooplankton density.

VIII. Zooplankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y_Z = 5226.0930 - 16.5260(x_1) - 8.7324 (x_2)-0.6383 (x_3) + 0.5724 (x_4) + 17.4829 (x_5) - 570.5082 (x_6) - 66.5546 (x_7) + 4.8779 (x_8) + 14.4465 (x_9) + 16.7196 (x_{10}) + 62.1818 (x_{11}) - 7.7674 (x_{12})$$

$$R^2 = 0.8064$$

The above twelve factors accounted for 80% of the variations of zooplankton density.

IX. Zooplankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y_Z = 5342.1098 - 13.8567 (x_1) - 9.2796 (x_2) - 0.6970 (x_3) + 0.1094 (x_4) + 17.0806 (x_5) - 583.7749 (x_6) - 64.1426 (x_7) + 4.2731 (x_8) + 13.9155 (x_9) + 17.3426 (x_{10}) - 70.1317 (x_{11})$$

$$R^2 = 0.8056$$

Therefore impact of eleven variables on zooplankton density was 80%.

X. Zooplankton vs. ten abiotic variables (x_1 - x_{10})

$$Y_Z = 4676.4268 - 10.2716 (x_1) - 8.6508 (x_2) - 0.75160 (x_3) + 3.1430 (x_4) + 15.22702 (x_5) - 556.2353 (x_6) - 70.7928 (x_7) + 2.7171 (x_8) + 19.2067 (x_9) + 33.9736 (x_{10})$$

$$R^2 = 0.7943$$

The stated ten abiotic factors accounted for 79% of variations of zooplankton density.

XI. Zooplankton vs. nine abiotic variables (x_1 - x_9)

$$Y_Z = 4459.4713 - 15.8857 (x_1) + 3.6901 (x_2) - 0.641750 (x_3) + 4.5821 (x_4) - 1.1625 (x_5) - 613.7350 (x_6) - 34.1418 (x_7) + 4.1851 (x_8) + 21.5155 (x_9)$$

$$R^2 = 0.7138$$

The stated nine abiotic factors also accounted for 71% of the variations of zooplankton density.

XII. Zooplankton vs. eight abiotic variables (x_1 - x_8)

$$Y_Z = 2441.4594 - 37.2527 (x_1) + 39.0780 (x_2) - 0.5188(x_3) + 4.4961 (x_4) + 1.0102 (x_5) - 474.6494 (x_6) - 2.7276 (x_7) - 1.1209 (x_8)$$

$$R^2 = 0.6411$$

The stated eight abiotic factors accounted for 64% of the variations in zooplankton density.

XIII. Zooplankton vs. seven abiotic variables (x_1 - x_7)

$$Y_Z = 3286.4402 - 48.3344 (x_1) + 47.9295 (x_2) - 0.9767 (x_3) + 1.3964 (x_4) - 1.2119(x_5) - 441.5809 (x_6) - 9.2360 (x_7)$$

$$R^2 = 0.5481$$

The stated seven abiotic factors accounted for 52% of the variations in zooplankton density.

XIV. Zooplankton vs. six abiotic variables (x_1 - x_6)

$$Y_Z = 3637.8870 - 44.0092 (x_1) + 49.9509 (x_2) - 1.3962 (x_3) - 1.2113 (x_4) - 2.0508 (x_5) - 452.0665 (x_6)$$

$$R^2 = 0.5299$$

The stated six abiotic factors accounted for 52% of the variations in zooplankton density.

SITE 2 (PEAT BOG)**Zooplankton (Y_Z) vs. 20 abiotic factors (x_1 - x_{20}): cumulative**

The multiple correlation of zooplankton (Y_Z) with twenty abiotic variables (x_1 - x_{20}) at Site 2 was computed and indicated the following regression equation:

$$Y_Z = 302.3546 - 1.3480 (x_1) + 1.2310 (x_2) - 0.1368 (x_3) - 0.9250 (x_4) - 1.3637(x_5) + 32.2794 (x_6) + 4.2709 (x_7) + 0.4666(x_8) - 0.6127 (x_9) + 14.1438(x_{10}) + 24.3613(x_{11}) + 4.6652 (x_{12}) - 0.4960 (x_{13}) - 7.5507 (x_{14}) - 15.5709 (x_{15}) + 121.2378 (x_{16}) + 265.7520 (x_{17}) + 4.1046(x_{18}) + 0.2322 (x_{19}) + 8.3432 (x_{20})$$

$$R^2 = 0.9941$$

Therefore, the stated twenty variables accounted for 99% of the variations in zooplankton densities at this site. However, step-wise regression indicated the following:

I. Zooplankton vs. nineteen abiotic variables (x_1 - x_{19})

$$Y_Z = 308.4811 - 1.3674 (x_1) + 1.3884 (x_2) - 0.1520 (x_3) - 0.9215 (x_4) - 1.3102 (x_5) + 31.8211 (x_6) + 4.2425 (x_7) + 0.4583 (x_8) - 0.6347 (x_9) + 14.1154 (x_{10}) - 25.1657(x_{11}) + 4.3746 (x_{12}) - 0.4525 (x_{13}) - 7.5196 (x_{14}) - 15.1488 (x_{15}) + 123.4363 (x_{16}) + 254.2037 (x_{17}) + 3.9047 (x_{18}) + 0.0027 (x_{19})$$

$$R^2 = 0.9936$$

The stated nineteen variables also accounted for 99% of the variations in zooplankton densities.

II. Zooplankton vs. eighteen abiotic variables (x_1 - x_{18})

$$Y_Z = 308.4944 - 1.3660 (x_1) + 1.3877 (x_2) - 0.1521 (x_3) - 0.9220 (x_4) - 1.3104(x_5) + 31.8183 (x_6) + 4.2422 (x_7) + 0.4585 (x_8) - 0.6350 (x_9) + 14.1174 (x_{10}) + 25.1688 (x_{11}) + 4.3739 (x_{12}) - 0.4508 (x_{13}) - 7.5223 (x_{14}) - 15.1498 (x_{15}) + 123.4767 (x_{16}) + 254.3330 (x_{17}) + 3.9065 (x_{18})$$

$$R^2 = 0.9936$$

Therefore, the above eighteen factors also accounted for 99% of variations in density of zooplankton.

III. Zooplankton vs. seventeen abiotic variables (x_1 - x_{17})

$$Y_Z = 286.1048 - 2.9611 (x_1) + 3.5784 (x_2) - 0.1748 (x_3) - 0.5183 (x_4) - 0.7413(x_5) + 23.4924 (x_6) + 4.5879 (x_7) + 0.0043 (x_8) + 0.0567 (x_9) + 11.6840 (x_{10}) + 25.1315 (x_{11}) + 2.4835 (x_{12}) - 1.0093(x_{13}) - 10.9609 (x_{14}) - 20.2173 (x_{15}) + 224.7801 (x_{16}) + 122.2404 (x_{17})$$

$$R^2 = 0.9643$$

Above seventeen variables accounted for 96% of the variations in zooplankton density.

IV. Zooplankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y_Z = 250.6235 - 2.8112 (x_1) + 4.0500 (x_2) - 0.1524 (x_3) - 0.4082 (x_4) - 0.4386(x_5) + 21.5011 (x_6) + 3.7294 (x_7) - 0.1264 (x_8) + 0.2365 (x_9) + 11.1691 (x_{10}) + 25.6758 (x_{11}) + 2.5041 (x_{12}) - 1.7678 (x_{13}) - 10.1560 (x_{14}) - 14.8100 (x_{15}) + 197.6524 (x_{16})$$

$$R^2 = 0.9586$$

The stated sixteen variables accounted for 95% of variations of zooplankton densities.

V. Zooplankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y_Z = 244.9149 - 1.9059 (x_1) + 2.4037 (x_2) + 0.0109 (x_3) - 0.1817 (x_4) - 0.3555 (x_5) + 29.7904 (x_6) + 1.0522 (x_7) + 0.0259 (x_8) + 0.2923 (x_9) + 10.1976 (x_{10}) - 23.2039 (x_{11}) + 1.9981 (x_{12}) - 2.2107 (x_{13}) - 6.7681 (x_{14}) - 1.1684 (x_{15})$$

$$R^2 = 0.9405$$

The above fifteen variables accounted for 94% of the variations in density of zooplankton.

VI. Zooplankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y_Z = 244.9149 - 1.9059 (x_1) + 2.4037 (x_2) + 0.0109 (x_3) - 0.1817 (x_4) - 0.3555 (x_5) + 29.7904 (x_6) + 1.0522 (x_7) + 0.0259 (x_8) + 0.2923 (x_9) + 10.1976 (x_{10}) + 23.2039(x_{11}) + 1.9981 (x_{12}) - 2.2107 (x_{13}) - 6.7681(x_{14})$$

$$R^2 = 0.9405$$

Above fourteen factors accounted for 94% of the variations in zooplankton density.

VII. Zooplankton vs. thirteen abiotic variables (x_1 - x_{13})

$$Y_Z = 244.9149 - 1.9059 (x_1) + 2.4037 (x_2) + 0.0109 (x_3) - 0.1817 (x_4) - 0.3555 (x_5) + 29.7904 (x_6) + 1.0522 (x_7) + 0.0259 (x_8) + 0.2923 (x_9) + 10.1976 (x_{10}) + 23.2039 (x_{11}) + 1.9981 (x_{12}) - 2.2107 (x_{13})$$

$$R^2 = 0.9405$$

The above thirteen abiotic factors accounted for 90% of the variations of zooplankton density.

VIII. Zooplankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y_Z = 152.1757 - 1.3595 (x_1) + 1.3842 (x_2) + 0.0678 (x_3) - 0.1719 (x_4) - 0.3976 (x_5) - 21.4166 (x_6) + 0.3678(x_7) + 0.1730 (x_8) + 0.4621 (x_9) + 9.1561 (x_{10}) - 23.1129 (x_{11}) + 2.0042 (x_{12})$$

$$R^2 = 0.8892$$

The above twelve factors accounted for 88% of the variations in zooplankton density.

IX. Zooplankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y_Z = 155.9732 - 1.2718 (x_1) + 1.1776 (x_2) + 0.0651 (x_3) - 0.2012 (x_4) - 0.3537 (x_5) - 21.2040 (x_6) - 0.3658 (x_7) + 0.2378 (x_8) + 0.5466 (x_9) + 9.3144 (x_{10}) - 22.2481 (x_{11})$$

$$R^2 = 0.882$$

Therefore above eleven variables accounted for 88% of the variations in zooplankton density.

X. Zooplankton vs. ten abiotic variables (x_1 - x_{10})

$$Y_Z = 34.2365 - 0.7195 (x_1) - 0.5116 (x_2) + 0.1802 (x_3) - 0.0320 (x_4) - 0.6937 (x_5) + 7.4579 (x_6) - 1.1326 (x_7) + 0.2788 (x_8) + 1.4053(x_9) + 3.5219(x_{10})$$

$$R^2 = 0.74$$

Above eight abiotic factors accounted for 74% of zooplankton density variations at this site.

XI. Zooplankton vs. nine abiotic variables (x_1 - x_9)

$$Y_Z = 52.1002 - 1.0516 (x_1) + 0.4095 (x_2) + 0.1254 (x_3) - 0.0557 (x_4) - 0.6268 (x_5) + 8.7723 (x_6) - 1.2224 (x_7) + 0.3716 (x_8) + 1.2574(x_9)$$

$$R^2 = 0.7204$$

The stated nine abiotic factors accounted for 72% of the variations in zooplankton density.

SITE 3 (PADDY-FIELD)**Zooplankton (Y_Z) vs. 19 abiotic factors (x_1 - x_{19}): cumulative**

The multiple correlation of zooplankton (Y_Z) with nineteen abiotic variables (x_1 - x_{19}) at Site 3 was computed and indicated the following regression equation:

$$Y_Z = -295.2655 + 4.0692 (x_1) - 5.2429 (x_2) + 0.0364 (x_3) - 0.3901 (x_4) + 50.2765 (x_5) + 4.1373 (x_6) + 1.7240 (x_7) + 2.1866 (x_8) + 1.4105 (x_9) + 3.3595 (x_{10}) + 0.9374 (x_{11}) - 3.7359 (x_{12}) + 2.1783 (x_{13}) - 86.1943 (x_{14}) - 25.2474 (x_{15}) + 1.0241 (x_{16}) + 9.586 (x_{17}) - 3.9117 (x_{18}) - 145.2462 (x_{19})$$

$$R^2 = 0.9685$$

Therefore, the stated nineteen variables accounted for 96% of the variations in zooplankton densities at this study site. However, step-wise regression indicated following regressions.

I. Zooplankton vs. eighteen abiotic variables (x_1 - x_{18})

$$Y_Z = 35.6979 + 0.4011 (x_1) - 0.6704 (x_2) + 0.0102 (x_3) - 0.5796 (x_4) - 0.0851 (x_5) + 1.2133 (x_6) + 1.0198 (x_7) + 1.8775 (x_8) + 0.9185 (x_9) - 2.5009 (x_{10}) - 5.2431 (x_{11}) + 4.3235 (x_{12}) + 3.0883 (x_{13}) - 530.8140 (x_{14}) - 1.8093 (x_{15}) + 1.0811 (x_{16}) - 2.1442 (x_{17}) + 14.280 (x_{18})$$

$$R^2 = 0.9466$$

The stated eighteen variables accounted for 94% of the variations in zooplankton densities.

II. Zooplankton vs. seventeen abiotic variables (x_1 - x_{17})

$$Y_Z = 2.3319 + 0.3176(x_1) - 1.0604 (x_2) - 0.0013 (x_3) - 0.5815 (x_4) + 5.1549(x_5) + 0.1593(x_6) + 0.8136 (x_7) + 1.9528(x_8) + 1.3162 (x_9) - 2.4614 (x_{10}) - 5.5784 (x_{11}) + 4.6329 (x_{12}) + 8.6239 (x_{13}) - 599.1188 (x_{14}) - 18.2315 (x_{15}) + 1.0545 (x_{16}) + 16.214 (x_{17})$$

$$R^2 = 0.9429$$

Therefore above seventeen abiotic factors accounted for 94% of variations in the density of zooplankton.

III. Zooplankton vs. sixteen abiotic variables (x_1 - x_{16})

$$Y_Z = 296.3441 + 2.9868 (x_1) - 0.6886 (x_2) + 0.1145 (x_3) + 0.4706 (x_4) - 50.7145 (x_5) + 5.7410 (x_6) + 0.8226 (x_7) + 0.3830 (x_8) - 2.5034 (x_9) - 2.7973 (x_{10}) - 4.1496 (x_{11}) + 3.3443 (x_{12}) + 9.2124 (x_{13}) - 334.3591 (x_{14}) - 87.7091 (x_{15}) + 17.047 (x_{16})$$

$$R^2 = 0.8672$$

Above sixteen variables accounted for 86% of the variation in zooplankton density.

IV. Zooplankton vs. fifteen abiotic variables (x_1 - x_{15})

$$Y_Z = 372.6442 - 0.0238 (x_1) + 1.5209 (x_2) + 0.0880 (x_3) - 0.0838 (x_4) - 50.5201 (x_5) + 2.5382 (x_6) - 0.2688 (x_7) - 0.2526 (x_8) + 25.2946 (x_9) - 96.6428 (x_{10}) - 4.6469 (x_{11}) - 7.3043 (x_{12}) + 2.1305 (x_{13}) + 12.0966 (x_{14}) - 565.9536 (x_{15})$$

$$R^2 = 0.8608$$

Therefore sixteen abiotic factors also accounted for 86% of the density variations.

V. Zooplankton vs. fourteen abiotic variables (x_1 - x_{14})

$$Y_Z = 225.4860 + 3.2635 (x_1) - 1.1463 (x_2) + 0.0724 (x_3) + 0.2961 (x_4) - 38.6317 (x_5) + 2.4300 (x_6) + 0.6210 (x_7) + 0.1119 (x_8) + 34.1526 (x_9) - 134.6262 (x_{10}) - 4.1028 (x_{11}) - 7.9284(x_{12}) + 9.6569 (x_{13}) + 5.4615 (x_{14})$$

$$R^2 = 0.7913$$

The above fourteen variables accounted for 79% of the variations in density of zooplankton.

VI. Zooplankton vs. thirteen abiotic variables (x_1 - x_{13})

$$Y_Z = 284.1888 + 2.4829 (x_1) - 0.0179 (x_2) + 0.0936 (x_3) + 0.3782 (x_4) - 46.9214 (x_5) + 3.0197 (x_6) + 0.7904 (x_7) - 0.1896 (x_8) + 40.9242 (x_9) - 163.6756 (x_{10}) - 4.5295 (x_{11}) - 7.7208(x_{12}) + 10.4837(x_{13})$$

$$R^2 = 0.7855$$

These thirteen factors accounted for 78% of the variations in zooplankton density.

VII. Zooplankton vs. twelve abiotic variables (x_1 - x_{12})

$$Y_Z = 173.992 + 0.5897 (X_1) + 0.2981 (X_2) + 0.1205 (X_3) + 0.0343 (X_4) - 23.1935 (X_5) + 5.1018 (X_6) + 1.4837 (X_7) + 0.0863 (X_8) + 15.8867 (X_9) - 55.9157 (X_{10}) - 4.9284 (X_{11}) - 7.1543 (X_{12})$$

$$R^2 = 0.7252$$

The cumulative effect of the above twelve factors accounted for 72% of variations in zooplankton density.

VIII. Zooplankton vs. eleven abiotic variables (x_1 - x_{11})

$$Y_Z = -41.9469 + 3.7599 (x_1) - 3.6085 (x_2) + 0.1176 (x_3) + 0.3336 (x_4) + 5.1822 (x_5) + 3.7916(x_6) + 1.8905 (x_7) + 0.5991 (x_8) - 5.2039 (x_9) + 30.3649 (x_{10}) - 3.7752(x_{11})$$

$$R^2 = 0.608$$

Therefore the above eleven variables explained for 60% of the variations in zooplankton density.

IX. Zooplankton vs. ten abiotic variables (x_1 - x_{10})

$$Y_Z = -21.4043 + 3.2645 (x_1) - 2.2674 (x_2) + 0.1037 (x_3) + 0.3370 (x_4) - 0.9092 (x_5) + 4.6464 (x_6) + 2.9832 (x_7) + 0.5393 (x_8) - 0.8526 (x_9) + 8.7918 (x_{10})$$

$$R^2 = 0.5879$$

Above ten factors accounted for 58% of the variations in the density of zooplankton.

X. Zooplankton vs. nine abiotic variables (x_1 - x_9)

$$Y_Z = -18.1460 + 3.2321 (x_1) - 2.2000 (x_2) + 0.1037 (x_3) + 0.3362 (x_4) - 1.4125 (x_5) + 4.6672 (x_6) + 2.9816 (x_7) + 0.5152 (x_8) + 1.2739 (x_9)$$

$$R^2 = 0.5878$$

The stated nine abiotic factors also accounted for 58% of the variations in the density of zooplankton.

TABLE 31: ANALYSIS OF VARIANCE (ANOVA)**a: Between months and three study sites****Abiotic Factors:**

Water Temperature	Sum of square	d.f.	Mean sum of square	F
Between months	1277.67	23	55.55	12.368
Between sites	140.92	2	70.46	15.687
Error	206.62	46	4.49	
Total	1625.21	71		

Rainfall

Between months	264518.33	23	11500.8	1.558
Between sites	152958.08	1	152958.08	20.715
Error	169832.26	23	7384.01	
Total		47		

Transparency

Between months	4538.61	23	197.33	1.228
Between sites	115597.03	1	115597.03	719.165
Error	3696.97	23	160.74	
Total	123832.61	47		

Specific Conductivity

Between months	7384.65	23	321.07	2.701
Between sites	4532.11	2	2266.06	19.061
Error	5468.56	46	118.88	
Total	17385.32	71		

pH

Between months	3.10	23	0.13	2.088
Between sites	7.41	2	3.70	57.352
Error	2.97	46	0.06	
Total	13.48	71		

Dissolved oxygen

Between months	204.98	23	8.91	2.877
Between sites	163.50	2	81.75	26.394
Error	142.48	46	3.10	
Total	510.97	71		

Free Carbon dioxide

Between months	1591.65	23	1424.70	1.574
Between sites	2849.40	2	43.97	32.399
Error	2022.76	46		
Total	6463.82	71		

Total Alkalinity

Between months	949.49	23	41.28	1.118
Between sites	387.25	2	193.62	5.245
Error	1698.17	46	36.92	
Total	3034.9	71		

Total Hardness	Sum of square	d.f.	Mean sum of square	F
Between months	1272.05	23	55.31	2.326
Between sites	394.07	2	197.04	8.288
Error	1093.55	46	23.77	
Total	2759.68	71		

Calcium

Between months	67.75	23	2.95	0.665
Between sites	68.18	2	34.09	7.698
Error	203.72	46	4.43	
Total	339.65	71		

Magnesium

Between months	76.75	23	3.34	2.109
Between sites	11.34	2	5.67	3.584
Error	72.77	46	1.58	
Total	160.86	71		

Sodium

Between months	120.00	23	5.22	3.383
Between sites	10.06	2	5.03	3.260
Error	70.94	46	1.54	
Total	201.00	71		

Potassium

Between months	200.83	23	8.73	1.901
Between sites	25.30	2	12.65	2.755
Error	211.27	46	4.59	
Total	437.39	71		

Chloride

Between months	37.04	23	1.61	1.561
Between sites	3.20	2	1.60	1.552
Error	47.46	46	1.03	
Total	87.70	71		

Sulphate

Between months	8.33	23	0.36	1.241
Between sites	26.03	2	13.01	44.594
Error	13.42	46	0.29	
Total	47.78	71		

Phosphate

Between months	0.031	23	0.001	1.903
Between sites	0.006	2	0.003	4.087
Error	0.033	46	0.001	
Total	0.070	71		
Total	0.394	71		

Nitrate	Sum of square	d.f.	Mean sum of square	F
Between months	0.159	23	0.007	1.540
Between sites	0.028	2	0.014	3.104
Error	0.207	46	0.004	
Total	0.394	71		

Silicate

Between months	3921.920	23	170.518	0.948
Between sites	1678.973	2	839.487	4.669
Error	8270.478	46	179.793	
Total	13871.373	71		

Dissolved organic matter

Between months	155.478	23	6.760	1.287
Between sites	57.256	2	28.628	5.452
Error	241.556	46	5.251	
Total	4554.290	71		

Total dissolved solids

Between months	0.466	23	0.020	0.854
Between sites	0.244	2	0.122	5.151
Error	1.091	46	0.024	
Total	1.801	71		

Species Richness

Net plankton

Between months	870.21	23	37.84	1.420
Between sites	751.00	2	375.50	14.093
Error	1225.67	46	26.64	
Total	2846.88	71		

Phytoplankton

Between months	185.78	23	8.08	1.406
Between sites	253.69	2	126.85	22.077
Error	264.31	46	5.75	
Total	703.78	71		

Zooplankton

Between months	610.65	23	26.55	1.730
Between sites	211.36	2	105.68	6.886
Error	705.97	46	15.35	
Total	1527.99	71		

Chlorophyceae

Between months	75.28	23	3.27	1.542
Between sites	33.69	2	16.85	7.937
Error	97.64	46	2.12	
Total	206.61	71		

Bacillariophyceae	Sum of square	d.f.	Mean sum of square	F
Between months	46.65	23	2.03	0.966
Between sites	127.44	2	63.72	30.358
Error	96.56	46	2.10	
Total	270.65	71		

Cyanophyceae

Between months	7.78	23	0.34	0.543
Between sites	2.69	2	1.35	2.164
Error	28.64	46	0.62	
Total	39.11	71		

Rotifera

Between months	172.44	23	7.50	1.445
Between sites	105.36	2	52.68	10.155
Error	238.64	46	5.19	
Total	516.44	71		

Cladocera

Between months	168.67	23	7.33	3.340
Between sites	8.33	2	4.17	1.898
Error	101.00	46	2.20	
Total	278.00	71		

Copepoda

Between months	9.28	23	0.40	3.151
Between sites	3.44	2	1.72	13.453
Error	5.89	46	0.13	
Total	18.61	71		

Rhizopoda

Between months	19.78	23	0.86	0.565
Between sites	31.36	2	15.68	10.308
Error	69.97	46	1.52	
Total	121.11	71		

Abundance

Net Plankton

Between months	496203.33	23	21574.05	0.6372
Between sites	25424.58	2	12711.79	0.375
Error	1557239.08	46	33853.02	
Total	2078866	71		

Phytoplankton

Between months	366063.98	23	15915.82	1.1782
Between sites	87131.69	2	43565.84	3.2251
Error	621380.30	46	13508.26	
Total	1074575.97	71		

Zooplankton	Sum of square	d.f.	Mean sum of square	F
Between months	482045.78	23	20958.51	1.0661
Between sites	206291.45	2	103145.72	5.2469
Error	904283.22	46	19658.33	
Total	1592620.45	71		

Chlorophyceae

Between months	30040.66	23	1306.12	0.779
Between sites	63994.08	2	31997.04	19.093
Error	77087.25	46	1675.80	
Total	171122	71		

Bacillariophyceae

Between months	52992.88	23	2304.04	1.536
Between sites	28824.33	2	14412.17	9.610
Error	68983.67	46	1499.64	
Total	150800.88	71		

Cyanophyceae

Between months	241398.17	23	10495.57	1.332
Between sites	4889.33	2	2444.67	0.310
Error	362556.00	46	7881.65	
Total	608843.50	71		

Euglenophyceae

Between months	217.32	23	9.45	0.930
Between sites	93.86	2	46.93	4.618
Error	467.47	46	10.16	
Total	778.65	71		

Rotifera

Between months	2259.94	23	98.26	1.625
Between sites	1262.19	2	631.10	10.438
Error	2781.14	46	60.46	
Total	6303.28	71		

Cladocera

Between months	9591.54	23	417.02	2.236
Between sites	885.08	2	442.54	2.373
Error	8578.25	46	186.48	
Total	19054.88	71		

Copepoda

Between months	406645.28	23	17680.23	1.045
Between sites	232251.19	2	116125.60	6.865
Error	778124.81	46	16915.76	
Total	1417021.28	71		

Rhizopoda	Sum of square	d.f.	Mean sum of square	F
Between months	965.99	23	42.00	1.826
Between sites	691.44	2	345.72	15.033
Error	1057.89	46	23.00	
Total	2715.32	71		

F- ratio significance level		
	1%	5%
Between months	2.37	1.84
Between sites	5.18	3.23

b: Between two years at Site 1 (pond)

Abiotic factors:

Water temperature	Sum of square	d.f.	Mean sum of square	F
Between months	352.73	11	32.07	23.132
Between years	2.04	1	2.04	1.473
Error	15.25	11	1.39	
Total	370.02	23		

Rainfall

Between months	149284.76	11	13571.34	11.769
Between years	334.51	1	334.51	0.290
Error	12684.76	11	1153.16	
Total	162304.03	23		

Transparency

Between months	4214.13	11	383.10	13.811
Between years	30.38	1	30.38	1.095
Error	305.13	11	27.74	
Total	4549.63	23		

Specific conductivity

Between months	2033.13	11	184.83	4.131
Between years	0.38	1	0.38	0.008
Error	492.13	11	44.74	
Total	2525.63	23		

pH

Between months	2.26	11	0.21	5.032
Between years	0.01	1	0.01	0.180
Error	0.45	11	0.04	
Total	2.72	23		

Dissolved oxygen

Between months	119.32	11	10.85	17.522
Between years	2.00	1	2.00	3.223
Error	6.81	11	0.62	
Total	128.13	23		

Free Carbon dioxide	Sum of square	d.f.	Mean sum of square	F
Between months	182.49	11	16.59	2.055
Between years	24.40	1	24.40	3.02
Error	88.82	11	8.07	
Total	295.71	23		

Total Alkalinity

Between months	182.49	11	16.59	2.055
Between years	24.40	1	24.40	3.022
Error	88.82	11	8.07	
Total	295.71	23		

Total Hardness

Between months	213.13	11	19.38	2.837
Between years	45.38	1	45.38	6.644
Error	75.13	11	6.83	
Total	333.63	23		

Calcium

Between months	30.02	11	2.73	1.291
Between years	0.07	1	0.07	0.031
Error	23.26	11	2.11	
Total	53.35	23		

Magnesium

Between months	10.36	11	0.94	1.211
Between years	3.91	1	3.91	5.027
Error	8.56	11	0.78	
Total	22.83	23		

Sodium

Between months	25.09	11	2.28	0.988
Between years	7.11	1	7.11	3.079
Error	25.39	11	2.31	
Total	57.59	23		

Potassium

Between months	45.42	11	4.13	3.530
Between years	11.54	1	11.54	9.862
Error	12.87	11	1.17	
Total	69.83	23		

Chloride

Between months	22.00	11	2.00	2.880
Between years	0.88	1	0.88	1.270
Error	7.64	11	0.69	
Total	30.52	23		

Sulphate

Between months	0.69	11	0.06	5.056
Between years	0.16	1	0.16	12.489
Error	0.14	11	0.01	
Total	0.99	23		

Phosphate	Sum of square	d.f.	Mean sum of square	F
Between months	0.0054	11	0.0005	2.577
Between years	0.0002	1	0.0002	1.264
Error	0.0021	11	0.0002	
Total	0.0077	23		

Nitrate

Between months	0.0137	11	0.0012	1.290
Between years	0.0001	1	0.0001	0.053
Error	0.0107	11	0.0010	
Total	0.0244	23		

Silicate

Between months	2424.3583	11	220.3962	1.671
Between years	235.6267	1	235.6267	1.787
Error	1450.7333	11	131.8848	
Total	4110.7183	23		

Dissolved organic matter

Between months	25.3844	11	2.3077	2.986
Between years	2.0709	1	2.0709	2.680
Error	8.5014	11	0.7729	
Total	35.9568	23		

Total dissolved solids

Between months	0.2580	11	0.0235	0.762
Between years	0.0392	1	0.0392	1.274
Error	0.3384	11	0.0308	
Total	0.6357	23		

Abundance

Net plankton	Sum of square	d.f.	Mean sum of square	F
Between months	730701.46	11	66427.41	1.931
Between years	80852.04	1	80852.04	2.350
Error	378475.46	11	34406.86	
Total	1190028.96	23		

Phytoplankton

Between months	94029.46	11	8548.13	3.670
Between years	477.04	1	477.04	0.205
Error	25619.46	11	2329.04	
Total	120125.96	23		

Zooplankton

Between months	943856.83	11	85805.17	2.712
Between years	68694.00	1	68694.00	2.171
Error	348069.00	11	31642.64	
Total	1360619.83	23		

Chlorophyceae	Sum of square	d.f.	Mean sum of square	F
Between months	2736.13	11	248.74	3.461
Between years	40.04	1	40.04	0.557
Error	790.46	11	71.86	
Total	3566.63	23		

Bacillariophyceae

Between months	10375.46	11	943.22	2.395
Between years	77.04	1	77.04	0.196
Error	4332.46	11	393.86	
Total	14784.96	23		

Cyanophyceae

Between months	56380.33	11	5125.48	6.804
Between years	368.17	1	368.17	0.489
Error	8286.83	11	753.35	
Total	65035.33	23		

Rotifera

Between months	250.13	11	22.74	2.136
Between years	3.38	1	3.38	0.317
Error	117.13	11	10.65	
Total	370.63	23		

Cladocera

Between months	8560.46	11	778.22	3.002
Between years	2.04	1	2.04	0.008
Error	2851.46	11	259.22	
Total	11413.96	23		

Copepoda

Between months	813182.13	11	73925.65	2.712
Between years	67734.38	1	67734.38	2.484
Error	299899.13	11	27263.56	
Total	1180815.63	23		

Rhizopoda

Between months	249.46	11	22.68	2.586
Between years	7.04	1	7.04	0.803
Error	96.46	11	8.77	
Total	352.96	23		

Species richness

Net plankton

Between months	363.46	11	33.04	1.622
Between years	45.38	1	45.38	2.227
Error	224.13	11	20.38	
Total	632.96	23		

Phytoplankton	Sum of square	d.f.	Mean sum of square	F
Between months	46.13	11	4.19	0.847
Between years	15.04	1	15.04	3.038
Error	54.46	11	4.95	
Total	115.63	23		

Zooplankton

Between months	234.83	11	21.35	1.343
Between years	8.17	1	8.17	0.514
Error	174.83	11	15.89	
Total	417.83	23		

Chlorophyceae

Between months	40.33	11	3.67	8.345
Between years	0.17	1	0.17	0.379
Error	4.83	11	0.44	
Total	45.33	23		

Bacillariophyceae

Between months	17.13	11	1.56	0.588
Between years	9.38	1	9.38	3.541
Error	29.13	11	2.65	
Total	55.63	23		

Cyanophyceae

Between months	7.13	11	0.65	2.280
Between years	0.38	1	0.38	1.320
Error	3.13	11	0.28	
Total	10.63	23		

Rotifera

Between months	50.50	11	4.59	2.164
Between years	2.67	1	2.67	1.257
Error	23.33	11	2.12	
Total	76.50	23		

Cladocera

Between months	115.83	11	10.53	3.174
Between years	1.50	1	1.50	0.452
Error	36.50	11	3.32	
Total	153.83	23		

Rhizopoda

Between months	18.46	11	1.68	1.220
Between years	0.38	1	0.38	0.273
Error	15.13	11	1.38	
Total	33.96	23		

c: Between two years at Site 2 (peat bog)**Abiotic factors**

Water temperature	Sum of square	d.f.	Mean sum of square	F
Between months	495.10	11	45.01	11.917
Between years	4.34	1	4.34	1.148
Error	41.54	11	3.78	
Total	540.98	23		

Rainfall

Between months	149284.76	11	13571.34	11.769
Between years	334.51	1	334.51	0.290
Error	12684.76	11	1153.16	
Total	162304.03	23		

Transparency

Between months	2764.46	11	251.31	3.198
Between years	57.04	1	57.04	0.726
Error	864.46	11	78.59	
Total	3685.96	23		

Specific conductivity

Between months	4811.13	11	437.38	24.489
Between years	40.04	1	40.04	2.242
Error	196.46	11	17.86	
Total	5047.63	23		

pH

Between months	1.47	11	0.13	6.906
Between years	0.01	1	0.01	0.581
Error	0.21	11	0.02	
Total	1.70	23		

Dissolved oxygen

Between months	27.54	11	2.50	0.605
Between years	0.20	1	0.20	0.047
Error	45.49	11	4.14	
Total	73.22	23		

Free Carbon dioxide

Between months	1074.26	11	97.66	0.615
Between years	15.52	1	15.52	0.098
Error	1745.64	11	158.69	
Total	2835.43	23		

Total alkalinity

Between months	888.46	11	80.77	1.755
Between years	3.38	1	3.38	0.073
Error	506.13	11	46.01	
Total	1397.96	23		

Total hardness	Sum of square	d.f.	Mean sum of square	F
Between months	463.93	11	42.18	2.532
Between years	96.80	1	96.80	5.810
Error	183.26	11	16.66	
Total	743.99	23		

Calcium

Between months	34.60	11	3.15	1.261
Between years	0.18	1	0.18	0.074
Error	27.44	11	2.49	
Total	62.22	23		

Magnesium

Between months	29.12	11	2.65	1.749
Between years	8.99	1	8.99	5.940
Error	16.65	11	1.51	
Total	54.76	23		

Sodium

Between months	29.19	11	2.65	2.097
Between years	7.40	1	7.40	5.850
Error	13.92	11	1.27	
Total	50.52	23		

Potassium

Between months	211.81	11	19.26	3.411
Between years	0.59	1	0.59	0.104
Error	62.10	11	5.65	
Total	274.49	23		

Chloride

Between months	12.58	11	1.14	1.999
Between years	1.45	1	1.45	2.535
Error	6.29	11	0.57	
Total	20.33	23		

Sulphate

Between months	7.14	11	0.65	2.597
Between years	1.14	1	1.14	4.547
Error	2.75	11	0.25	
Total	11.03	23		

Phosphate

Between months	0.033	11	0.003	3.520
Between years	0.006	1	0.006	7.254
Error	0.009	11	0.001	
Total	0.048	23		

Nitrate

Between months	0.025	11	0.002	1.382
Between years	0.002	1	0.002	1.012
Error	0.018	11	0.002	
Total	0.044	23		

Silicate	Sum of square	d.f.	Mean sum of square	F
Between months	164.924	11	14.993	2.108
Between years	49.738	1	49.738	6.993
Error	78.234	11	7.112	
Total	292.895	23		

Dissolved organic matter

Between months	148.206	11	13.473	4.179
Between years	37.851	1	37.851	11.740
Error	35.464	11	3.224	
Total	221.520	23		

Total dissolved solids

Between months	0.501	11	0.046	3.711
Between years	0.004	1	0.004	0.326
Error	0.135	11	0.012	
Total	0.640	23		

Abundance

Net plankton

Between months	271204.83	11	24654.98	2.515
Between years	47170.67	1	47170.67	4.812
Error	107832.33	11	9802.94	
Total	426207.83	23		

Phytoplankton

Between months	238688.83	11	21698.98	1.908
Between years	60601.50	1	60601.50	5.329
Error	125089.50	11	11371.77	
Total	424379.83	23		

Zooplankton

Between months	6106.33	11	555.12	2.890
Between years	840.17	1	840.17	4.374
Error	2112.83	11	192.08	
Total	9059.33	23		

Chlorophyceae

Between months	54074.46	11	4915.86	1.758
Between years	6370.04	1	6370.04	2.278
Error	30757.46	11	2796.13	
Total	91201.96	23		

Bacillariophyceae

Between months	27647.13	11	2513.38	2.168
Between years	2709.38	1	2709.38	2.337
Error	12755.13	11	1159.56	
Total	43111.63	23		

Cyanophyceae	Sum of square	d.f.	Mean sum of square	F
Between months				
Between years	12696.00	1	12696.00	2.460
Error	56775.00	11	5161.36	
Total	135855.83	23		

Rotifera

Between months	346.13	11	31.47	0.850
Between years	45.38	1	45.38	1.226
Error	407.13	11	37.01	
Total	798.63	23		

Cladocera

Between months	3296.50	11	299.68	2.326
Between years	640.67	1	640.67	4.972
Error	1417.33	11	128.85	
Total	5354.50	23		

Copepoda

Between months	688.46	11	62.59	2.128
Between years	12.04	1	12.04	0.410
Error	323.46	11	29.41	
Total	1023.96	23		

Rhizopoda

Between months	1022.46	11	92.95	13.732
Between years	7.04	1	7.04	1.040
Error	74.46	11	6.77	
Total	1103.96	23		

Species Richness

Net plankton

Between months	652.46	11	59.31	1.516
Between years	1.04	1	1.04	0.027
Error	430.46	11	39.13	
Total	1083.96	23		

Phytoplankton

Between months	96.13	11	8.74	1.230
Between years	0.38	1	0.38	0.053
Error	78.13	11	7.10	
Total	174.63	23		

Zooplankton

Between months	329.83	11	29.98	1.742
Between years	2.67	1	2.67	0.155
Error	189.33	11	17.21	
Total	521.83	23		

Chlorophyceae	Sum of square	d.f.	Mean sum of square	F
Between months	30.13	11	2.74	1.662
Between years	0.38	1	0.38	0.228
Error	18.13	11	1.65	
Total	48.63	23		

Bacillariophyceae

Between months	12.13	11	1.10	0.839
Between years	0.04	1	0.04	0.032
Error	14.46	11	1.31	
Total	26.63	23		

Cyanophyceae

Between months	7.83	11	0.71	4.273
Between years	0.17	1	0.17	1.000
Error	1.83	11	0.17	
Total	9.83	23		

Rotifera

Between months	80.13	11	7.28	2.260
Between years	1.04	1	1.04	0.323
Error	35.46	11	3.22	
Total	116.63	23		

Cladocera

Between months	42.83	11	3.89	
Between years	0.17	1	0.17	
Error	32.83	11	2.98	
Total	75.83	23		

Rhizopoda

Between months	24.83	11	2.26	3.548
Between years	0.00	1	0.00	0.000
Error	7.00	11	0.64	
Total	31.83	23		

d: Between two years at Site 3 (paddy field)

Abiotic factors

Water Temperature	Sum of square	d.f.	Mean sum of square	F
Between months				
Between years	20.720	1	20.720	2.997
Error	76.045	11	6.913	
Total	573.286	23		

Rainfall

Between months	228793.035	11	20799.367	5.698
Between years	3103.100	1	3103.100	0.850
Error	40150.425	11	3650.039	
Total	272046.560	23		

Specific conductivity	Sum of square	d.f.	Mean sum of square	F
Between months				
Between years	234.375	1	234.375	2.224
Error	1159.125	11	105.375	
Total	5279.958	23		

pH

Between months	0.760	11	0.069	1.208
Between years	0.263	1	0.263	4.585
Error	0.630	11	0.057	
Total	1.653	23		

Dissolved oxygen

Between months	59.739	11	5.431	0.842
Between years	15.440	1	15.440	2.394
Error	70.931	11	6.448	
Total	146.110	23		

Free Carbon dioxide

Between months	166.265	11	15.115	0.928
Between years	13.350	1	13.350	0.820
Error	179.135	11	16.285	
Total	358.750	23		

Total alkalinity

Between months	371.433	11	33.767	0.706
Between years	56.427	1	56.427	1.180
Error	526.133	11	47.830	
Total	953.993	23		

Total hardness

Between months	919.593	11	83.599	2.971
Between years	58.907	1	58.907	2.094
Error	309.493	11	28.136	
Total	1287.993	23		

Calcium

Between months	91.504	11	8.319	1.593
Between years	6.955	1	6.955	1.332
Error	57.432	11	5.221	
Total	155.891	23		

Magnesium

Between months	56.065	11	5.097	5.738
Between years	6.090	1	6.090	6.856
Error	9.771	11	0.888	
Total	71.926	23		

Sodium

Between months	45.737	11	4.158	1.241
Between years	0.242	1	0.242	0.072
Error	36.855	11	3.350	
Total	82.834	23		

Potassium	Sum of square	d.f.	Mean sum of square	F
Between months				
Between years	13.425	1	13.425	4.813
Error	30.681	11	2.789	
Total	67.772	23		

Chloride

Between months	10.943	11	0.995	0.613
Between years	4.860	1	4.860	2.995
Error	17.850	11	1.623	
Total	33.653	23		

Sulphate

Between months	5.686	11	0.517	1.433
Between years	0.087	1	0.087	0.242
Error	3.969	11	0.361	
Total	9.742	23		

Phosphate

Between months	0.005123	11	0.000466	1.716
Between years	0.000002	1	0.000002	0.006
Error	0.002986	11	0.000271	
Total	0.008110	23		

Nitrate

Between months	0.130815	11	0.011892	0.809
Between years	0.006403	1	0.006403	0.435
Error	0.161740	11	0.014704	
Total	0.298958	23		

Silicate

Between months	6306.775	11	573.343	4.409
Between years	51.627	1	51.627	0.397
Error	1430.383	11	130.035	
Total	7788.785	23		

Dissolved organic matter

Between months	6306.775	11	573.343	4.409
Between years	51.627	1	51.627	0.397
Error	1430.383	11	130.035	
Total	7788.785	23		

Total dissolved solids

Between months	0.0885	11	0.0080	0.461
Between years	0.0011	1	0.0011	0.061
Error	0.1920	11	0.0175	
Total		23		

Abundance

Net plankton	Sum of square	d.f.	Mean sum of square	F
Between months				
Between years	65835.38	1	65835.38	5.032
Error	143930.13	11	13084.56	
Total	437205.63	23		

Phytoplankton

Between months	246145.50	11	22376.86	1.630
Between years	45762.67	1	45762.67	3.333
Error	151030.33	11	13730.03	
Total	442938.50	23		

Zooplankton

Between months	7703.83	11	700.35	1.078
Between years	1802.67	1	1802.67	2.776
Error	7143.33	11	649.39	
Total	16649.83	23		

Chlorophyceae

Between months	3194.33	11	290.39	0.496
Between years	2730.67	1	2730.67	4.668
Error	6434.33	11	584.94	
Total	12359.33	23		

Bacillariophyceae

Between months	44694.46	11	4063.13	2.489
Between years	1426.04	1	1426.04	0.873
Error	17959.46	11	1632.68	
Total	64079.96	23		

Cyanophyceae

Between months	170311.50	11	15482.86	0.929
Between years	42000.67	1	42000.67	2.521
Error	183278.33	11	16661.67	
Total	395590.50	23		

Euglenophyceae

Between months	232.83	11	21.17	1.054
Between years	20.17	1	20.17	1.005
Error	220.83	11	20.08	
Total	473.83	23		

Rotifera

Between months	2192.83	11	199.35	1.311
Between years	6.00	1	6.00	0.039
Error	1673.00	11	152.09	
Total	3871.83	23		

Cladocera	Sum of square	d.f.	Mean sum of square	F
Between months	626.33	11	56.94	1.055
Between years	181.50	1	181.50	3.364
Error	593.50	11	53.95	
Total	1401.33	23		

Copepoda

Between months	1262.50	11	114.77	1.140
Between years	560.67	1	560.67	5.570
Error	1107.33	11	100.67	
Total	2930.50	23		

Rhizopoda

Between months	273.46	11	24.86	1.079
Between years	40.04	1	40.04	1.738
Error	253.46	11	23.04	
Total	566.96	23		

Species Richness

Net plankton

Between months	168.46	11	15.31	0.862
Between years	15.04	1	15.04	0.847
Error	195.46	11	17.77	
Total	378.96	23		

Phytoplankton

Between months	59.83	11	5.44	0.833
Between years	28.17	1	28.17	4.313
Error	71.83	11	6.53	
Total	159.83	23		

Zooplankton

Between months	226.46	11	20.59	1.525
Between years	2.04	1	2.04	0.151
Error	148.46	11	13.50	
Total	376.96	23		

Chlorophyceae

Between months	29.46	11	2.68	1.073
Between years	22.04	1	22.04	8.830
Error	27.46	11	2.50	
Total	78.96	23		

Bacillariophyceae

Between months	27.46	11	2.50	0.965
Between years	5.04	1	5.04	1.949
Error	28.46	11	2.59	
Total	60.96	23		

Cyanophyceae	Sum of square	d.f.	Mean sum of square	F
Between months	11.46	11	1.04	2.570
Between years	0.04	1	0.04	0.103
Error	4.46	11	0.41	
Total	15.96	23		

Rotifera

Between months	108.46	11	9.86	1.113
Between years	12.04	1	12.04	1.359
Error	97.46	11	8.86	
Total	217.96	23		

Cladocera

Between months	31.00	11	2.82	3.509
Between years	0.17	1	0.17	0.208
Error	8.83	11	0.80	
Total	40.00	23		

Rhizopoda

Between months	11.46	11	1.04	0.945
Between years	0.38	1	0.38	0.340
Error	12.13	11	1.10	
Total	23.96	23		

F- ratio significance level

	1%	5%
Between months	4.40	2.79
Between years	9.65	4.84

DISCUSSION

Limnology has come a long way in different parts of the world (Kalff, 2002) in understanding the dynamics of inland waters. Role of water in nature is unique not only from the point of human consideration but also for those numerous organisms living in it. The present study carried out in varied freshwater environs of Bhutan for the first time brings into limelight water quality in aquatic habitats, diversity of plankton in general and zooplankton in particular and synecology of these micro-organisms in relation to abiotic and biotic parameters. The detailed limnological investigations in three selected ecosystems in eastern Bhutan along with biodiversity of Rotifera, the dominant qualitative component of zooplankton, in aquatic ecosystems mainly of eastern Bhutan were undertaken and the results are discussed below:

I. ABIOTIC FACTORS:

Temperature: Temperature exerts the most profound direct or indirect influence on physico-chemical, biological, metabolic and physiological state of aquatic ecosystems (Welch, 1982). It also indirectly modifies the effect of other factors (Clarke, 1954; Barbose, 1981) and influences the dynamics of living organisms (Chandler, 1942). It regulates growth, turnover rates and production of aquatic communities (Wetzel, 1983). During the present study, air temperature at Site 1 (pond), Site 2 (peat bog) and Site 3 (paddy-field) ranged between 13.1-28.9° C ($18.4 \pm 4.3^\circ$ C), 10.5-28.8° C ($18.2 \pm 5.0^\circ$ C) and 9.4-28.3° C ($21.2 \pm 5.7^\circ$ C) respectively. Similarly water temperature ranged between 10.5-24.9° C ($17.2 \pm 4.0^\circ$ C), 9.1-26.0° C ($16.4 \pm 4.9^\circ$ C) and 9.0-25.6° C ($19.7 \pm 4.9^\circ$ C) at Sites 1-3 respectively. ANOVA indicated significant variations in water temperature between months ($F_{23, 46} = 12.368$, $P < 0.01$) as well as between three sampling sites ($F_{2, 46} = 15.687$, $P < 0.01$). However, no significant annual variations occurred in any of the ecosystems ($P > 0.05$). Further, in other sampled water bodies (Sites 4-24), air and water temperatures ranged more widely i.e., between 2.0-32.0° C ($18.0 \pm 8.0^\circ$ C) and 1.1-29.5° C ($17.2 \pm 8.0^\circ$ C) respectively. The recorded annual variations at Sites 1-3 and mean values at all other sites corresponded with sub-tropical nature of the lakes of Pokhara, Nepal (Swar and Fernando, 1979) and lentic ecosystems of Meghalaya (Sharma, 1995, 2001; Sharma and Lyngdoh, 1999; Sharma and Wanswett, 1999; Sharma and Lynsgkor, 2003).

Water temperature was influenced by air temperature and registered a significant direct correlation with the latter at all three regularly monitored study sites 1-3 ($r_1 = 0.851$, $r_2 = 0.900$ and $r_3 = 0.935$). Highest correlation between the stated parameters at Site 3 (paddy-field) is attributed to shallow nature of this ecosystem. Water temperature registered a positive correlation with rainfall ($r_1 = 0.855$, $r_2 = 0.567$) in the pond (Site 1) and the peat bog (Site 2) and pH in peat bog and paddy-field ($r_2 = 0.539$, $r_3 = 0.422$). Besides, it depicted inverse correlations with transparency ($r_1 = -0.810$, $r_2 = -0.577$) and with sulphate ($r_1 = -0.553$, $r_2 = -0.633$) in the pond and the peat bog; with dissolved oxygen ($r_1 = -0.823$, $r_3 = -0.416$) in the pond and the paddy-field; with free CO₂ ($r_1 = -0.539$) in the pond and with specific conductivity ($r_2 = -0.554$) and potassium ($r_2 = -0.445$) in the peat bog.

Rainfall: It is an important factor responsible for recharging the water level. Besides, rainfall influences water chemistry and controls biological productivity (Moss, 1988). Major volume of rainfall in Bhutan is owing to monsoon, which prolongs between mid May-September. In the present study, higher mean rainfall was recorded at Site 1 (pond) and Site 2 (peat bog) and ranged between 5.0-225.0 mm (100.4 ± 84.0 mm). On the other hand monthly variations in rainfall at Site 3 (paddy-field), showed wider range i.e., between 0.7-364.0 mm (94.9 ± 108.8 mm) with most of the precipitation occurring between May-September at both the locations. Further, ANOVA also exhibited significant variations in rainfall between the sites ($F_{1, 23} = 20.715$, $P < 0.01$) but annual variations in all sites were insignificant ($P > 0.05$). However, total annual rainfall was higher during the first year at all sites with 1250 mm and 1160.4 mm at Sites 1 and 2 and 1275 mm and 1002.1 mm at Site 3 during first and second year of the study respectively.

Rainfall exerted its influence on various abiotic factors at all sites with variable degree as indicated by their correlation values. It registered positive correlation only with specific conductivity ($r_1 = 0.411$) and sulphate ($r_1 = 0.621$) in pond (Site 1) and with calcium ($r_3 = 0.520$) in the paddy-field (Site 3). However, it exhibited inverse relationships with specific conductivity at Site 2 ($r_2 = -0.406$). Inverse relationships also existed between rainfall and transparency at Sites 1 and 2 ($r_1 = -0.784$, $r_2 = -0.660$). This fact could be due to increased runoff entering into water bodies from catchments along with surface soil and debris during rainy seasons. Such a generalisation concurred with reports by Sharma and Lyngdoh (1999) and Sharma and Wanswett (1999) in some water bodies of Meghalaya. In

addition, rainfall depicted negative correlations with dissolved oxygen in the pond ($r_1 = -0.778$) and with sulphate ($r_2 = -0.486$) and total dissolved solids ($r_2 = -0.652$) in the peat bog.

Transparency: Transparent waters allow more light penetration, thereby, causing far-reaching effects on aquatic organisms including their development, distribution and behaviour (Kaushik and Saksena, 1999). Transparency at Site 1 (pond) ranged widely with comparatively higher mean value i.e., between 65.0-110.0 cm (89.6 ± 14.1) and with narrow ranges at Site 2 (peat bog) between 55.0-95.0 cm (79.5 ± 12.7 cm) during the present study. The observed values at both sites are lower than the report of Swar and Fernando (1979) from some lakes of Nepal but are broadly identical to Umiam reservoir, Meghalaya (Sharma and Lyngdoh, 1999). Generally low transparency in the presently sampled water bodies could be mainly due to small nature of water bodies and the canopy as well as thick growth of macrophytes around the water bodies. Further, transparency in the pond was relatively higher than in the peat bog as also indicated by significant variations between two sites ($F_{1, 23} = 719.165$, $P < 0.01$). This is apparently owing to thicker vegetation around its fringes as well as due to higher abundance of filamentous algae in the water of the peat bog. However, there were no significant variations in transparency between two years in both the water bodies. However, it was lower during the rainy season and was relatively higher during the winter months in both Site 1 and Site 2. The former aspect is substantiated by its high negative correlation with rainfall ($r_1 = -0.784$, $r_2 = -0.660$) at both sites. Further, a positive relationship was noted between transparency and dissolved oxygen at Site 1 ($r_1 = 0.648$). Several factors that were directly related to transparency in peat bog included total hardness ($r_2 = 0.456$), potassium ($r_2 = 0.489$), sulphate ($r_2 = 0.481$) and total dissolved solids ($r_2 = 0.586$). However, transparency exhibited inverse relationships with specific conductivity ($r_1 = -0.456$), free CO_2 ($r_1 = -0.566$) and total alkalinity ($r_1 = -0.470$) in the pond and with pH ($r_2 = -0.484$) in the peat bog.

Specific Conductivity: Ionic concentration of aquatic ecosystems is attributed to dissolved salts in water and is measured as specific conductance of electrolytes which, in turn, depicts total conductivity of various ionizable salts present (Jhingran, 1982). Specific conductivity at all three studied sites was low and ranged between 22-62 $\mu\text{S}/\text{cm}$ ($33.4 \pm 10.5 \mu\text{S}/\text{cm}$) in

pond, 17-62 $\mu\text{S}/\text{cm}$ ($43.4 \pm 14.8 \mu\text{S}/\text{cm}$) in peat bog and 33-88 $\mu\text{S}/\text{cm}$ ($52.8 \pm 15.2 \mu\text{S}/\text{cm}$) in paddy-field. Monthly variations exhibited an annual maxima in early summer at all sites and minima during monsoon; the later could be due to the dilution effect of the rainwater. ANOVA indicated significant variations in specific conductivity between months ($F_{23, 46} = 2.701$, $P < 0.05$) as well as between sites ($F_{2, 46} = 19.061$, $P < 0.01$). However, no significant annual differences were recorded within the study sites. Relatively higher mean in the paddy-field is attributed to frequent ploughing and puddling, thereby, discharging of ions into the surface water. Recorded conductivity values concurred with reports from Nepal (Hickel, 1973) and some water bodies of Meghalaya (Sharma and Wanswett, 1999; Sharma and Lyngdoh, 1999) as well as of Khechopelri lake of Sikkim (Jain *et al.*, 1999). However, mean values at Site 3 (paddy-field) are greater than the report by Jyrwa (1996) in Ummolong paddy-field in Meghalaya. Further, the specific conductivity recorded at Sites 4-24 in diverse ecosystems ranged more widely between 12-500 $\mu\text{S}/\text{cm}$ ($71.4 \pm 99.2 \mu\text{S}/\text{cm}$) with highest conductivity recorded in eutrophic sewage stabilization pond (Site 5). However in the remaining sampled water bodies, relatively narrow range between 16-142 $\mu\text{S}/\text{cm}$ ($52.8 \pm 38.8 \mu\text{S}/\text{cm}$) was recorded, thereby, indicating generally low mineral ions in these waters of Bhutan. Above observations are concurrent with reports of Dhendup and Boyd (1994) except one of the locations at Haa in western Bhutan (170 $\mu\text{S}/\text{cm}$) reported by them. Similarly, the present values are broadly identical to water bodies of Meghalaya (Sharma, 2001) but are slightly higher than the reports of Swar and Fernando (1979). However, specific conductivity values recorded are considerably lower than reports of some wetlands of Kashmir (Pandit, 1999) and also of Anchar Lake in that state (Sarwar, 1999).

Specific conductivity showed direct relationship with rainfall in the pond ($r_1 = 0.411$), thereby, indicating the role of rainwater in adding ionizable salts into the water. Significant direct correlations were also seen with total alkalinity ($r_2 = 0.456$), total hardness ($r_3 = 0.515$), calcium ($r_1 = 0.820$), magnesium ($r_3 = 0.434$), nitrate ($r_1 = 0.508$), sulphate ($r_1 = 0.582$, $r_2 = 0.610$), potassium ($r_2 = 0.728$), sodium ($r_2 = 0.637$) and dissolved organic matter ($r_2 = 0.440$), thereby, indicating contributory role of these factors in ionic content of the sampled water bodies. In addition, specific conductivity inversely correlated with pH ($r_1 = -0.551$, $r_2 = -0.505$) in the pond (Site 1) and the peat bog (Site 2) and dissolved oxygen ($r_1 = -0.663$) in the former ecosystem.

pH: Hydrogen ion concentration of natural waters is governed to a large extent by the interaction between H^+ and OH^- ions formed due to dissociation of H_2CO_3 and hydrolysis of bicarbonates respectively (Wetzel, 1983). pH of raw water sources mostly lies within the range of 6.50-8.50 (Webber and Stumm, 1963). During present study, pH at Sites 1-3 ranged between 6.53-7.80 (6.91 ± 0.34), 5.69-6.58 (6.17 ± 0.27) and 6.21-7.41 (6.75 ± 0.27) respectively, thereby depicting slightly acidic-alkaline character of Site 1 (pond) and Site 3 (paddy-field) and a typical 'acidic nature' of Site 2 (peat-bog). In addition, narrow ranges at all three sites depicted their buffered conditions. ANOVA indicated significant variations in pH between months ($F_{23, 46} = 2.088$, $P < 0.05$) as well as between sites ($F_{2, 46} = 57.352$, $P < 0.01$). In the pond, subsequent to monsoon, pH marginally exceeded its mean value (pH 7.2) in first year, while it increased significantly (pH 7.8) during the second year. However, at Site 2, water was acidic throughout the study period exhibiting a typical peat bog environment (Horne and Goldman, 1994). On the other hand, paddy-field (Site 3) depicted significant variations in pH during the two annual cycles of study period ($F_{1, 11} = 4.585$, $P < 0.05$) with wider range and higher mean (pH 6.9) during first year in comparison to comparatively more acidic condition of the second year (mean pH 6.6).

Hydrogen ion concentration in other sampled water bodies (Sites 4-24) ranged broadly between 6.24-8.29 (6.8 ± 0.5) depicting an acidic nature of a glacial lake (pH 6.20) > small man made pond (pH 6.24); distinctly alkaline nature of the sewage stabilization pond (pH 8.29) > a paddy-field (pH 7.6) > an artificial resort pond = a fishery pond (pH 7.45); and circum-neutral characters of most other water bodies. Following the classification by Venkateswarlu (1983), waters in eight of the sites fall within 'acidophilus' category (pH 5.5-6.7) and two in the alkaliphilus (pH 7.5-9.0). The remaining fourteen water bodies would fall under 'indifferent' (pH 6.5-7.5) or circum-neutral types. Recorded range and mean values broadly correspond with lentic ecosystems of Meghalaya (Sharma, 2001) but is marginally lower than earlier reports by Dhendup and Boyd (1994) in some ponds in Bhutan. Similarly, the recorded ranges and mean values are also lower than Begnas and Rupa lakes in Nepal (Swar and Fernando, 1979) as well as some wetlands in Kashmir in the far western Himalayas (Quadri and Yousuf, 1988; Pandit, 1999) and in three lakes in Kumaon Hill (Singh, *et al.*, 1982).

pH exhibited positive correlation with water temperature ($r_2 = 0.559$, $r_3 = 0.442$) in the peat bog (Site 2) and paddy-field (Site 3) and with dissolved oxygen ($r_1 = 0.546$) in the pond (Site 1). Besides, it shared inverse relationships with several factors namely, total hardness ($r_1 = -0.590$, $r_3 = -0.496$) at Sites 1 and 3; phosphate ($r_1 = -0.465$, $r_2 = -0.467$) at Sites 1 and 2; potassium ($r_2 = -0.590$, $r_3 = -0.454$) at Sites 2 and 3; specific conductivity ($r_1 = -0.551$) and sulphate ($r_1 = -0.442$) at Site 1 and total alkalinity ($r_3 = -0.432$) and magnesium ($r_3 = -0.582$) at Site 3.

Dissolved Oxygen: Dissolved oxygen is an important indicator of trophic status of aquatic environs and is the basis for distribution, behaviour and growth of aquatic organisms (Wetzel, 1983). During the present study, dissolved oxygen exhibited significant differences among three study sites registering greater oxygenation in the paddy-field, the monthly variations of which ranged between 2.4-13.6 mg/l (7.0 ± 2.5 mg/l). In the pond relatively moderate oxygen was seen as it ranged between 2.4-10.8 mg/l (5.4 ± 2.3 mg/l). However, in the peat bog it registered narrow range and low mean between 1.2-9.6 mg/l (3.37 ± 1.78 mg/l) with corresponding mean oxygen percentage saturation of 27% in this ecosystem. ANOVA indicated significant variations of dissolved oxygen concentration between months ($F_{23, 46} = 2.877$, $P < 0.01$) as well as between the sampled sites ($F_{2, 23} = 26.394$, $P < 0.01$), while the annual values were identical at all three sites. Well-oxygenated pond and the paddy-field are identical to most aquatic environs of Meghalaya (Sharma, 2001), while poorly oxygenated peat bog (Site 2) resembled with Nartiang peat bog in the above mentioned state (Lyngdoh, 1998). Low oxygen content in the peat bog could be attributed to higher rate of utilization of oxygen for decomposition of debris. Nevertheless, George (1961) maintained that a concentration of 1.4 mg/l of oxygen is sufficient to maintain life in water and this lower critical point was marginally exceeded in this peat bog during November in second year of study (1.2 mg/l).

Further, dissolved oxygen content ranged between 2.3-16.0 mg/l (7.3 ± 3.7 mg/l) at all other sampled study sites (Sites 4-24). While some of the shallow water bodies including paddy-fields (Sites 16 and 18) showed lower values of 3.5 mg/l and 2.3 mg/l respectively, poor oxygenation was also recorded in eutrophic waters of sewage stabilization pond (2.4 mg/l) owing to high level of organic matter caused by decomposing algal bloom (Horne and Goldman, 1994). Other sampled water body with low oxygen

content (3.84 mg/l) included a small man-made pond. However, higher dissolved oxygen in two glacial lakes (16.0 mg/l and 11.0 mg/l respectively) could be due to greater diffusion of oxygen at low temperature (Ray *et al.*, 1966; Mathew, 1975; Agrawal *et al.*, 1976; Mishra and Yadava, 1978; Sikandar and Tripathi, 1984 and Shukla *et al.*, 1989) and also apparently due to low community respiration. Relatively higher values were recorded in water bodies from lower altitudes including Site 11 (12.2 mg/l) > Site 10 (12 mg/l) > Site 9 (11.2 mg/l), apparently owing to higher partial pressure (Wetzel, 1983). Even though ranges in the present study vary more widely, mean dissolved oxygen values are identical to the reports of Sarwar (1999), Pandit (1999) and Sharma (2001).

Regarding monthly and seasonal variations in dissolved oxygen content at Sites 1-3, higher oxygen was recorded in pre- and post-monsoon months in the paddy-field (Site 3). Similarly, lower values were recorded in the pond (Site 1) during the rainy seasons as also supported by inverse correlation with rainfall ($r_1 = -0.778$). Further, higher values of dissolved oxygen during dry months could be attributed to higher transparency during this season, which was also supported by positive correlation with transparency ($r_1 = 0.648$). However, negative role of temperature in solubility of oxygen was well expressed by the inverse relationships in the pond and the paddy-field ($r_1 = -0.823$, $r_3 = -0.416$). This finding is concurrent with various earlier reports (Ray *et al.*, 1966; Mathew, 1975; Agrawal *et al.*, 1976; Mishra and Yadava, 1978; Sikandar and Tripathi, 1984 and Shukla *et al.*, 1989). Further, positive relation of dissolved oxygen is recorded with sulphate ($r_2 = 0.501$) in the peat bog and chloride ($r_3 = 0.594$) in the paddy-field while an inverse correlation is also noticed with sulphate ($r_1 = -0.630$) in the pond.

Free Carbon dioxide: Free CO₂ contributes to the fitness of natural waters (Kaushik and Saksena, 1999) because it serves as a buffer and exists in equilibrium with bicarbonate and carbonate ions (Wetzel, 1983). During the present study significant variations in free Carbon dioxide was observed between the sites as indicated by ANOVA ($F_{2, 46} = 32.399$, $P < 0.01$). It was recorded throughout the study period in the pond and the peat bog and ranged between 3.2-24.0 mg/l (7.1 ± 4.3 mg/l) and 11.2-65.0 mg/l (19.5 ± 11.1 mg/l) respectively thereby reflecting its poor autotrophic uptake in those ecosystems. In addition, significant annual variations were recorded in the peat bog ($F_{1, 11} = 9.65$, $P < 0.01$) with highest concentration of free CO₂ in the peat bog (65.0 mg/l) recorded in April during first

year when water level was low and was accompanied with greater decomposition of organic matter. On the other hand, free CO₂ was not recorded in the paddy-field in October during the first year of study, which could be owing to greater rate of photosynthesis as it also coincided with the highest population density of phytoplankton of corresponding annual cycle. It ranged between 0.0-20.0 mg/l (5.4 ± 4.0 mg/l) with highest concentration in June during the first year, which could be apparently due to greater rate of decomposition during the plantation activities. Of all the three sites, higher CO₂ during the entire study period was recorded in the peat bog and this finding is concurrent to the reports in Nartiang peat bog in Meghalaya, (Lyngdoh, 1998) where even higher records of free CO₂ was made. This unique characteristic feature of the peat bog is owing to a large quantity of algae, *Sphagnum* sp. and other macrophytes including leaves and other floral parts from shrubs and trees getting constantly decomposed in its water.

Free CO₂ in all the other sampled water bodies (Sites 4-24) ranged widely between 2.0-19.5 mg/l (6.6 ± 4.6 mg/l) with maximum values observed in a shallow pond (Site 20) at 3150 m ASL in eastern Bhutan, and minimum in a fishpond at the foothills (Site 14). While mean value of free CO₂ corresponded with the reports of Sharma (1995) and Sharma and Wanswett (1999), it is lower than the reports of Quadri and Yousuf (1988) and Sharma and Lyngdoh (1999).

Free CO₂ exhibited relatively lesser influence on other abiotic factors at Sites 1-3. Nevertheless, direct relationship was noted with total alkalinity ($r_1 = 0.591$) at Site 1 (pond) and with calcium ($r_3 = 0.550$) and sulphate ($r_3 = 0.416$) at Site 3 (paddy-field). In addition, inverse correlations were indicated with water temperature ($r_1 = -0.539$), transparency ($r_1 = -0.566$) and total hardness ($r_1 = -0.605$) in the pond.

Total alkalinity: In the present investigations, alkalinity was exclusively attributed to methyl orange alkalinity, which, in turn, was contributed by bicarbonate ions. The observed values were low i.e., between 17.0-30.0 mg/l (24.8 ± 3.6 mg/l), 11.0-36.0 mg/l (22.2 ± 7.8 mg/l) and 16.8-40.0 mg/l (27.9 ± 6.4 mg/l) at Sites 1-3 respectively and did not register significant differences between two annual cycles. However, ANOVA indicated significant variations between the sampling sites ($F_{2, 46} = 5.245$, $P < 0.01$). Generally, total alkalinity was low during rainy season in the pond and the peat bog owing to the dilution effect of the rainwater. While, there were relatively lesser monthly fluctuations in the pond, the peat bog

depicted distinct bimodal patterns of variations with peak in June during first year and maxima in January 2001 (34.0 mg/l), May 2001 (28.0 mg/l) and November-December, 2001 (34.0 mg/l each). On the other hand, in the paddy-field, higher total alkalinity coincided with the paddy plantation activities and distinct maxima were recorded in August first year and June in second year of study. However, maxima of lower magnitudes were also seen in pre-paddy seasons during both annual cycles of study period, which could be due to concentration of the nutrients prior to rainfall in this ephemeral ecosystem.

Besides, in all other water bodies (Sites 4-24), total alkalinity ranged between 13.1-240.0 mg/l (40.9 ± 47.1 mg/l) with highest values exhibited by sewage stabilisation pond (Site 5). When the latter is excluded, range and mean values reduced substantially to 13.1-80.0 mg/l (30.95 ± 21.39 mg/l), thereby, indicating 'moderately hard' waters at Site 13 = Site 10 (80.0 mg/l each) > Site 19.0 (68.0 mg/l) > Site 15 (64.0 mg/l) > Site 6 = Site 18 (40.0 mg/l) and 'soft water' at all other 17 sites (*vide* Moyle, 1946; Phillopose, 1960; Wetzel, 1983; Payne, 1986). Above six ecosystems with moderate hard water characteristic vary from a river-fed recreational pond (Site 13) to weedy and shallow water ponds (Sites 6, 10, 15 and 19) and from a paddy-field (Site 18) to occasionally limed fishpond (Site 14). Therefore, 70% of the sampled biotopes represented broadly 'soft water' characteristic (21.7 ± 7.16 mg/l) of lentic waters in Bhutan. The recorded values concurred with the earlier reports from Bhutan by Dhendup and Boyd (1994). Similarly, moderate alkalinity in six of the sites is considerably higher than waters from Meghalaya (Sharma, 2001) as well as from a lake of Sikkim (Jain *et al.*, 1999). However, range and mean alkalinity at 17 other sites (including Sites 1-3) correspond with cited reports. On the other hand, the present mean values are considerably lower than reports from Kumaon and Kashmir (Singh, *et al.*, 1982; Quadri and Yousuf, 1988; Pandit, 1999 and Sarwar, 1999).

Total alkalinity exerted positive relationships with free CO₂ ($r_1 = 0.591$) at Site 1 (pond) and with total hardness ($r_3 = 0.632$), calcium ($r_3 = 0.407$) and magnesium ($r_3 = 0.500$) at Site 3 (paddy-field), which, in turn, reflected interdependence of these attributes. Similarly at Site 2 (peat bog), a direct correlation was computed with specific conductivity ($r_2 = 0.456$), nitrate ($r_2 = 0.670$), dissolved organic matter ($r_2 = 0.554$) and silicate ($r_2 = 0.528$). On the other hand, inverse relationship of alkalinity was noted only with transparency ($r_1 = -0.470$) and pH ($r_3 = -0.432$) in the pond and paddy-field respectively.

Total Hardness: Total hardness is mainly attributed to calcium and magnesium along with other cations such as potassium and sodium in combination with anions like bicarbonate and carbonate (temporary hardness) and with sulphate and chloride (permanent hardness). In the studied biotopes, total hardness ranged between 11.0-26.0 mg/l (16.4 ± 3.8 mg/l), 10.0-34.0 mg/l (18.3 ± 5.7 mg/l) and 4.0-40.0 mg/l (22.0 ± 7.5 mg/l) respectively during the study period. Further, ANOVA indicated significant variations between months ($F_{23, 46} = 2.326$, $P < 0.05$) as well as between sites ($F_{2, 46} = 8.288$, $P < 0.01$). In addition, significant annual variations were also noted at Site 1 ($F_{1, 11} = 6.664$, $P < 0.05$) as well as at Site 2 ($F_{1, 11} = 5.810$, $P < 0.05$), while they were identical in the paddy-field. Total hardness ranged more widely with relatively higher mean during the second annual cycle in the pond as well as the peat bog, apparently due to lower annual rainfall during the second year, thereby, imparting relatively lesser dilution effect on various factors. The recorded values depicted 'soft-water' characteristics (*vide* Sawyer, 1960; Ohle, 1934 and Swingle, 1946) of these regularly monitored biotopes.

At other sampled water bodies (Sites 4-24), total hardness ranged more widely between 7.0-76.0 mg/l (24.1 ± 18.3 mg/l) and thus broadly corresponded with the reports of Dhendup and Boyd (1994). Present observations depicted a 'very soft' nature of Site 12 (7.0 mg/l) > Site 7 (8.8 mg/l) > Site 11 (9.6 mg/l) > Site 23 (10.0 mg/l) > Site 4 = Site 13 (11.0 mg/l) > Site 20 = Site 22 (12.0 mg/l) in the decreasing order of total hardness, representing diverse ecosystems located at different altitudes. On the contrary, moderately 'hard-water' at Site 5 (76.0 mg/l) > Site 19 (62.0 mg/l) > Site 14 (58.0 mg/l), in turn, representing a sewage stabilisation pond, a weedy and a marshy pond and a fishpond respectively, were recorded. All other 13 sampled biotopes fall under the category of 'soft-waters' as per the classification *vide* Ohle (1934), Moyle (1946) and Payne (1986). Total hardness in presently sampled water bodies of Bhutan is considerably lower than the reports of Quadri and Yousuf (1988), Sarwar (1999) and Pandit (1999) from western Himalayas, while the recorded values are largely identical to the 'soft waters' of Meghalaya state of Eastern Himalayas (Sharma, 1999; Sharma and Wanswett, 1999; Sharma, 2001; Sharma and Sharma, 2001).

In general, total hardness was relatively higher in pre- and post-monsoon months in the regularly monitored water bodies (Sites 1-3). Generally, lower hardness in monsoon could be attributed to dilution effect by the rainwater. However, in the paddy-field (Site 3),

smaller maxima (25.0 mg/l) was also observed in September indicating impact of human activities during the paddy season in this ecosystem. Correlation computed between total hardness and other abiotic factors indicated direct relationship with magnesium at all sites ($r_1 = 0.729$, $r_2 = 0.896$, $r_3 = 0.938$) and with calcium at Site 1 ($r_1 = 0.814$). Therefore, role of magnesium in contributing to total hardness across three study sites was more pronounced than any other ion. Positive correlation of total hardness also existed with other abiotic factors including sodium ($r_1 = 0.488$, $r_2 = 0.479$, $r_3 = 0.532$) at all sites and potassium ($r_1 = 0.7814$, $r_2 = 0.656$) at Sites 1 and 2; with transparency ($r_2 = 0.456$) at Site 2 (peat bog) and specific conductivity ($r_3 = 0.515$) and total alkalinity ($r_3 = 0.632$) at Site 3 (paddy-field). On the other hand, inverse correlation was exhibited with dissolved organic matter ($r_1 = -0.501$) and silicate ($r_1 = -0.554$) in the pond and with pH ($r_3 = -0.496$) in the paddy-field.

Calcium: The present study indicated low calcium content at all three sites and it ranged between 2.94-8.4 mg/l (4.85 ± 1.52 mg/l), 3.15-8.4 mg/l (5.55 ± 1.64 mg/l) and 4.2 –13.65 mg/l (7.17 ± 2.6 mg/l) respectively during the study period. Significant variations in calcium content were noted between the sites ($F_{2, 46} = 7.698$, $P < 0.01$) but insignificant between months. While pond depicted a bimodal pattern of monthly variations with maxima in early summer (June) in first year and during spring in second year, peat bog depicted its peak in autumn in first year, while it showed regular fluctuations with multimodal pattern during the second year. Further, significant annual variations were observed in the peat bog ($F_{1, 11} = 9.650$, $P < 0.01$). On the other hand, in the paddy-field, higher quantity of calcium was recorded during the paddy season and less in pre- and post paddy seasons with distinct peak in August during first year and a maxima (12.6 mg/l) in June during second year. The latter fact could be attributed to agricultural practices during the paddy season, which result in leaching out of calcium ions into surface water. This aspect also concurred with the reports by Jyrwa (1996) in Ummlong paddy-field in Meghalaya. All three sampled water bodies above could be classified as calcium ‘poor’ (mean < 10 mg/l) *vide* Ohle (1938).

Calcium ranged more broadly between 2.5-41.0 mg/l (9.9 ± 10.0 mg/l) at all other sites (4-24) with maximum concentration in sewage stabilization pond. However, in rest of the sampled water bodies, it ranged between 2.5-29.4 mg/l (7.4 ± 6.1 mg/l). Site19 (29.4 mg/l) $>$ Site 15 (27.3 mg/l), represented relatively ‘calcium rich’ condition; Site 14 (21.0

mg/l) > Site10 (13.7 mg/l) > Site 18 = Site 6 (12.6 mg/l) are waters with 'medium' calcium content comprising a limed fish pond (Site 14) to small ponds (Sites 6 and 10) and a paddy-field (Site 18); and the remaining 17 sites (70% of the sampled water bodies) affirmed 'calcium poor' conditions (*vide* Ohle, 1938). Recorded calcium content concurred with the reports of Dhendup and Boyd (1994). But it was significantly lower than the reports by Pandit (1999) and Sarwar (1999). While the present result is also lower than in Nainital Lake (Singh *et al.*, 1982), it concurred with the findings in Naukuchiatal Lake communicated in the above report. In addition, the presently recorded values are also identical to waters of Meghalaya (Sharma, 1995, 1999, 2000; Jyrwa, 1996; Sharma and Wanswett, 1999; Sharma and Lyngdoh, 1999).

Calcium showed significant positive correlations with specific conductivity ($r_1 = 0.820$), total dissolved solids ($r_2 = 0.442$), total alkalinity ($r_3 = 0.407$) and carbon dioxide ($r_3 = 0.550$) at various study sites. Further, a positive correlation of calcium is recorded with rainfall in the paddy-field ($r_3 = 0.520$). However, inverse relationship between rainfall and calcium in the peat bog ($r_2 = -0.549$) apparently indicated 'dilution effect' of the former.

Magnesium: It is an important component of chlorophyll, a co-factor in enzymatic transformations (Wetzel, 1983) and is also a factor that contributes to total hardness of water. Its content at all three sites was low and indicated significant variations between months ($F_{23, 46} = 2.109$, $P < 0.05$) as well as between sites ($F_{2, 46} = 3.584$, $P < 0.05$). While monthly magnesium content varied with a narrow range and relatively lower mean i.e., between 0.87-4.53 mg/l (2.64 ± 1.0 mg/l) in the pond, relatively wider ranges were recorded at other two sites, which in turn, ranged between 1.13-8.11 mg/l (3.2 ± 1.54 mg/l) in the peat bog and 1.6-8.34 mg/l (3.6 ± 1.77 mg/l) in the paddy-field. In addition, annual ranges and mean values also varied between two years at all sites with relatively wider ranges and higher mean values during second year. Significant annual variations in magnesium content was also indicated by ANOVA at all sites i.e., $F_{1, 11} = 5.027$, $P < 0.05$, at Site 1, $F_{1, 11} = 5.940$, $P < 0.05$ at Site 2 and $F_{1, 11} = 6.865$, $P < 0.05$ at Site 3. Generally low magnesium content was recorded during monsoon at all sites, which could be due to uptake of magnesium by the floral components of the water body during this period.

Magnesium at all other sampled water bodies (Sites 4-24) was also low, and ranged between 0.6-8.52 mg/l (3.42 ± 2.38 mg/l). In addition, magnesium was lesser than calcium

at all sites and this aspect concurred with the reports of Grimshaw and Hudson (1970), Sondergaard and Sand-Jensen (1979), Khan and Zutshi (1980b), Zutshi (1981), Gopal *et al.*, (1981), Jhingran (1991) and Sharma and Wanswett (1999). While the present mean value of magnesium was only slightly lower than the reports of Sarwar (1999), it is significantly lower than the reports of Pandit (1999) but broadly corresponded with reports of Dhendup and Boyd (1994) and Sharma (2001).

The role of magnesium in contributing to total hardness is clearly indicated by significant positive correlations with the later at all sites ($r_1 = 0.729$, $r_2 = 0.896$, $r_3 = 0.938$). Further, a significant positive correlation is observed with potassium ($r_1 = 0.621$, $r_2 = 0.703$) and sodium ($r_1 = 0.439$, $r_3 = 0.514$). Besides, it also registered direct correlations with specific conductivity ($r_3 = 0.434$) and alkalinity ($r_3 = 0.500$) at Site 3. On the other hand, negative relationship is recorded with pH ($r_3 = -0.582$) in the paddy-field; dissolved organic matter ($r_1 = -0.515$) and total dissolved solids ($r_1 = -0.439$) in the pond and with nitrate ($r_2 = -0.584$) and silicate ($r_2 = -0.635$) in the peat bog.

Sodium: This alkaline earth metal is required in low concentration for plant growth and for pumping in potassium across cell membranes. It is generally abundant in water and is metabolised by blue-green algae (Jhingran, 1982). During the present study, it registered narrow ranges between 1.17-6.68 mg/l (3.54 ± 1.58 mg/l), 2.0-6.8 mg/l (4.0 ± 1.48 mg/l) and 1.0-8.35 mg/l (4.46 ± 1.9 mg/l) at Sites 1-3 respectively. ANOVA depicted significant variations of sodium between months ($F_{23, 46} = 3.383$, $P < 0.01$) as well as between the three sites ($F_{2, 46} = 3.260$, $P < 0.05$). Further, no substantial variations were seen in annual ranges and mean values at Site 2 (peat bog) as well as Site 3 (paddy-field), while relatively higher sodium content was observed at Site 1 (pond) during the second year of study which ranged between 2.2-6.68 mg/l (4.09 ± 1.78 mg/l). The later could be attributed to lower annual rainfall in second year, thereby, lesser dilution by rainwater, compared to the first year. Further, in the pond, trimodal pattern was seen with maxima in February (5.0 mg/l) August (4.34 mg/l) and December (4.7 mg/l) in first year and February (6.68 mg/l), June (3.7 mg/l) and November (6.8 mg/l) in second year of the study period. The peat bog registered a unimodal pattern of monthly variations during the first year with maxima (6.2 mg/l) in March and a bimodal pattern in second year with peak in November (6.8 mg/l) and secondary maxima (6.51 mg/l) in February, thereby exhibiting higher concentration during

dry seasons. On the other hand, in the paddy-field, a bimodal pattern of monthly variation was recorded during first year with maxima in March (6.2 mg/l) and August (6.84 mg/l) and a trimodal pattern was observed during the second year with peak in February (8.35 mg/l) and other maxima in August (5.2 mg/l) and December (4.67 mg/l). Mean values at all sites are identical to the reports of Dhendup and Boyd (1994) and also fall within ranges reported in 'moderate altitude lakes' of North-Western Himalayas (Zutshi, 1989). On the other hand, the recorded values are marginally lower than the reports of Sharma and Wanswett (1999) in sub-tropical Cheerapunji ponds while they are considerably lower than some man-made reservoirs and tanks in Gwalior city, India (Kaushik and Saksena, 1999). Further, during the present study, sodium exhibited direct relationship with total hardness ($r_2 = 0.479$, $r_3 = 0.532$) in the peat bog and paddy-field and with potassium ($r_2 = 0.524$) in the peat bog, while inverse relationship with pH ($r_3 = -0.436$) was recorded in the paddy-field.

Potassium: It is generally present in adequate quantity in the freshwater bodies and is used as an enzyme activator in the cells (Horne and Goldman, 1994). Under low potassium condition blue-green algae decline in their density (Wetzel, 1975). Its content in the studied biotopes ranged between 2.5-9.25 mg/l (5.38 ± 1.74 mg/l), 1.75-13.5 mg/l (5.29 ± 3.4 mg/l) and 2.0-8.0 mg/l (4.06 ± 1.782 mg/l) at Sites 1-3 respectively. The recorded values were higher than the reports in some basins of Dal Lake in Kashmir (Kaul, 1988) and also higher than the reports of Dhendup and Boyd (1994). However, they were identical to the results of Sarwar (1999) and Sharma and Wanswett (1999). Generally higher concentration of this alkaline metal was recorded during dry months due to evaporation of water (Kaushik and Saksena, 1999) at all sites. ANOVA indicated significant variations in potassium content between months ($F_{23, 46} = 1.901$, $P < 0.05$) and insignificant between the sampling sites. In addition, pond registered bimodal pattern of monthly variations of this metal with maxima in March (6.2 mg/l) and July (6.15 mg/l) during first year and February (9.25 mg/l) and July (8.25 mg/l) in second year. ANOVA also indicated significant annual variations ($F_{1, 11} = 9.862$, $P < 0.01$) in the pond but there were no significant differences in the other two sites. On the other hand, in the peat bog it depicted trimodal pattern in first year with maxima depicted in March (10.0 mg/l), June (9.0 mg/l) and December (9.0 mg/l) and a unimodal pattern in second year with peak concentration in February (13.5 mg/l). On the

other hand, paddy-field registered lesser fluctuations of this conservative element and depicted maxima of lower magnitudes during the two annual cycles of the study period, which occurred in pre-paddy seasons. Potassium exhibited direct relationship with total hardness in the pond and the peat bog ($r_1 = 0.781$, $r_2 = 0.656$), thereby, contributing significantly to total hardness in these water bodies. Further, it also positively correlated with other abiotic factors, including magnesium ($r_1 = 0.601$, $r_2 = 0.703$) and sodium ($r_1 = 0.601$, $r_2 = 0.524$) at Site 1 (pond) and Site 2 (peat bog); and with sulphate ($r_2 = 0.590$), specific conductivity ($r_2 = 0.728$) and transparency ($r_2 = 0.489$) at Site 2. On the other hand, potassium showed inverse relationship with water temperature ($r_2 = -0.445$), pH ($r_2 = -0.590$) and nitrate ($r_2 = -0.590$) at Site 2 and with nitrate ($r_3 = -0.454$) in the paddy-field (Site 3).

Chloride: Chloride is formed generally from dissolution of salt deposits of sodium, potassium and calcium and is usually found in low concentration in natural waters (Wetzel, 1983). However, influx from domestic sewage could sufficiently raise its content, thereby, indicating organic pollution in water bodies. Chloride content registered low mean values and narrow ranges during the present study i.e., between 2.5-6.6 mg/l (4.2 ± 1.2 mg/l) in the pond, 2.8-6.2 mg/l (4.7 ± 0.9 mg/l) in the peat bog and 2.0-7.0 mg/l (4.6 ± 1.2 mg/l) in the paddy-field. ANOVA did not indicate significant variations in chloride between months or between the sampling sites as well as in annual values within each site. Therefore, lesser temporal variations in concentration of this halide in three regularly monitored water bodies affirmed its conservative nature. However, at all other sampled biotopes (Sites 4-24), it ranged more widely between 2.1-42.0 mg/l (7.4 ± 8.0 mg/l) with highest chloride concentration registered at Site 5 (sewage stabilisation pond), which indicated presence of organic pollutants. With exclusion of the later, chloride content in other remaining water bodies ranged between 2.1-14.0 mg/l (5.9 ± 3.2 mg/l), reflecting lack of organic pollution (Wetzel, 1983). The recorded values correspond with the reports of Jain, *et al.*, (1999) and Sharma (2001) but are marginally higher than the reports of Dhendup and Boyd (1994). However, the chloride content in the present study is slightly lower than the report of Pandit (1999) but substantially lower than the report of Sarwar (1999). It showed significant positive correlation with only dissolved oxygen ($r_3 = 0.594$) in the paddy-field. However, inverse relationship was seen with silicate ($r_2 = -0.553$, $r_3 = -0.722$) and total dissolved

solids ($r_2 = -0.494$, $r_3 = -0.432$) in peat bog and the paddy-field and with specific conductivity ($r_2 = -0.464$) and dissolved organic matter ($r_2 = -0.683$) in the peat bog.

Sulphate: Sulphur is an important component of proteins, responsible for three-dimensional structure of enzymes and regulates cell division (Horne and Goldman, 1994). During the present study, sulphate was low at all sites and fluctuated between 0.12-0.76 mg/l (0.41 ± 0.21 mg/l) with lowest mean in the pond followed by 0.85-2.99 mg/l (1.59 ± 0.69 mg/l) in the peat bog and 0.92-3.059 mg/l (1.77 ± 0.65 mg/l) in the paddy-field. ANOVA indicated significant variations in sulphate content between sites ($F_{23, 46} = 1.901$, $P < 0.05$). In addition, Site 1 (pond) registered significant variations between two years of study as also indicated by ANOVA ($F_{1, 11} = 12.489$, $P < 0.01$). It registered higher mean during the first year (0.50 ± 0.23 mg/l) compared to second year (0.33 ± 0.14 mg/l) with marginally higher concentration of sulphate during rainy seasons. This fact could be attributed to influx of surface debris into the pond along with rainwater, which is further substantiated by positive correlation between sulphate and rainfall ($r_1 = 0.621$). On the other hand, peat bog registered maxima in pre-monsoon months, apparently owing to concentration of the nutrient. Similarly in the paddy-field, sulphate depicted higher concentrations during pre- and post paddy seasons with peak (3.06 mg/l) in May during the second year. The latter could be due to decomposition of weeds and debris aided by ploughing and puddling in the beginning of paddy season. Recorded ranges and mean values at all sites fall below or within the normal range of 1-30 mg/l reported to occur in freshwater (Wetzel, 1983). Sulphate content in the present study is marginally lower than earlier report of Dhendup and Boyd (1994) and distinctly lower than most observations made in some lentic habitats of Meghalaya (Jyrwa, 1996; Lakiang, 1998; Lyngdoh, 1998). However, the values are identical to reports by Sharma and Wanswett (1999) in some ponds of Cheerapunji and also in Malse reservoir (Sharma, 1995). During the present study, sulphate shared positive correlation with conductivity ($r_1 = 0.532$, $r_2 = 0.610$) in the pond and the peat bog; with phosphate ($r_1 = 0.410$) and dissolved organic matter ($r_1 = 0.413$) in the pond; with transparency ($r_2 = 0.0481$), potassium ($r_2 = 0.590$) and dissolved oxygen ($r_2 = 0.501$) in the peat bog and with free CO_2 ($r_3 = 0.416$) in the paddy-field. On the other hand, indirect relationship is seen with dissolved oxygen ($r_1 = -0.650$), water temperature

($r_1 = -0.553$) and pH ($r_1 = -0.442$) at Site 1 (pond) and with water temperature ($r_2 = -0.633$) and rainfall ($r_2 = -0.486$) at Site 2 (peat bog).

Phosphate: Phosphate is a key nutrient in biological productivity (Hutchinson, 1957) as it is a component of nucleic acid and other important metabolites in the cells. Phosphate, in the present study, was very low at all three sites and ranged between 0.004-0.06 mg/l (0.03 ± 0.02 mg/l), 0.006-0.17 mg/l (0.05 ± 0.05) and 0.006-0.078 mg/l (0.02 ± 0.02 mg/l) respectively. The recorded values at all sites were, however, identical to the reports of Dhendup and Boyd (1994) and Quadri and Yousuf (1988) but lower than the reports of Zutshi *et al.*, (1980), Negi *et al.*, (1983), Vass *et al.*, (1989) and Sharma (2001). In general, low phosphate could be attributed to weathered nature of the rocks and leaching of this micronutrient from the soil. The observed values at all sites in general exhibited relatively higher concentration of phosphate during early summer (April-May), which could be apparently due to increased concentration of this nutrient owing to reduced water level. In addition, low phosphate during the mid-monsoon at all sites could be attributed to the dilution effect of rainwater as also reported by Stewart and Markello (1974) and Sonderguard and Sand-Jensen (1979).

ANOVA exhibited significant variations between months ($F_{23, 46} = 1.903$, $P < 0.05$) as well as between the sites ($F_{2, 46} = 4.087$, $P < 0.05$). In the pond (Site 1), unimodal pattern of monthly variations in first year and a bimodal in second year was seen with maxima in April (0.06 mg/l) in first year and in June (0.05 mg/l) and January (0.05 mg/l) in second year. On the other hand, peat bog (Site 2) depicted significant variation between its annual values ($F_{1, 11} = 7.254$, $P > 0.05$) with a distinctly high peak in first year during May (0.17 mg/l) and a maxima of relatively lower magnitude (0.09 mg/l) in the same month during the second year. Further a relatively higher mean was recorded during the first year (0.06 ± 0.06) in comparison to second year (0.03 ± 0.03 mg/l). Of all the study sites, minimum phosphate concentration was recorded in the paddy-field and it was found to be still lower during the peak paddy season, which could be due to greater utilization of this scarce nutrient. Further, this micronutrient correlated positively with few other abiotic parameters at various study sites namely sulphate ($r_1 = 0.410$), total dissolved solids ($r_1 = 0.421$, $r_3 = 0.441$) and inversely with pH ($r_1 = -0.465$, $r_2 = -0.467$).

Nitrate: It is a stable form of nitrogen, which in turn, is an indispensable element required for synthesis of proteins and nucleic acids. Nitrate in water serves as an essential micronutrient for autotrophic production. Nitrate concentration during the present study ranged between 0.009-0.17 mg/l (0.06 ± 0.003 mg/l), 0.003-0.18 mg/l (0.1 ± 0.04 mg/l) and 0.01-0.506 mg/l (0.1 ± 0.11 mg/l) at Sites 1-3 respectively. Generally low nitrate content in these biotopes depicted low usage of nitrogenous fertilisers in the catchment area (Malthus and Mitchell, 1988, 1990), White (1983) and Sharma (1995). The observed values are slightly lower than the reports of Quadri and Yousuf (1988), Dhendup and Boyd (1994), Nongtraw (1998) and significantly lower than the reports by Sharma (1995). However, the values are identical with various other reports from Meghalaya (Jyrwa, 1996; and Lakiang, 1999; Sharma and Lyngdoh, 1999; Sharma and Wanswett, 1999).

Further, nitrate at Site 1 (pond) and Site 3 (paddy-field) varied marginally in its annual ranges and mean values exhibiting higher values during the first year at Site 1 and the same trend is noted at Site 3 during the second year. A relatively higher nitrate recorded prior to monsoon at Site 2 (peat bog) could be due to concentration of this nutrient due to evaporation as well as low rainfall (5-80 mm) during those dry months. However in the paddy-field, higher nitrate concentration was recorded during pre-paddy season till early paddy season, owing to ploughing and subsequent decomposition of weeds and rice stubble (Jyrwa, 1996), and low during the later part of paddy season. The later fact could be due to uptake of this indispensable nutrient by the paddy. While nitrate did not share any significant relationship with other abiotic factors at Site 1 (pond), significant positive correlation is seen with dissolved organic matter ($r_2 = 0.701$, $r_3 = 0.674$) in the peat bog and the paddy-field as well as with silicate ($r_2 = 0.567$) in the peat bog. On the other hand, inverse relationship of nitrate was indicated with total hardness ($r_2 = -0.496$), magnesium ($r_2 = -0.584$) and potassium ($r_2 = -0.590$) in the peat bog (Site 2).

Silicate: All three sites registered relatively high quantity of silicates, which could be owing to rock weathering and inflow of water rich in silts and sediments (Hutchinson, 1957; Seenaya, 1977). The quantity of silicate in three sampled water bodies (Sites 1-3) varied significantly as also indicated by ANOVA ($F_{23, 46} = 4.669$, $P < 0.05$) and ranged broadly between 2.5-62.5 mg/l (13.7 ± 13.4) in the pond and 20.4-60.0 mg/l (20.4 ± 18.4 mg/l) in the paddy-field. However, a narrow range and comparatively low mean i.e., 2.5-

15.0 mg/l (8.6 ± 3.6 mg/l) was registered in the peat bog (Site 2). Further, silica content was generally higher during late summer in the pond and in early summer in paddy-field and low during winter in both these water bodies. This fact could be attributed to influx of allochthonous silicic acid and particulate silica during summer (Wetzel and Moss, 1988). The impact of temperature on silicate concentration is further affirmed by their positive relationship ($r_3 = 0.407$) in the paddy-field. Further, the latter registered highest silica content among three sites, which could be attributed to constant ploughing and mixing of soil in addition to irrigation by sandy stream waters. In addition, maxima in May (50.0 mg/l) during the first year and peak in July (60.0 mg/l) during second year in this ecosystem coincided with those agricultural activities. Similarly, a relatively wider range and higher mean was seen in the pond (Site 1) with peak silicate content (62.5 mg/l) in September during second year. This fact could be attributed to influx of silt and sediment rich rainwater during the latter month. However, relatively low values were recorded in pre- as well as post monsoon months due to greater sedimentation.

On the other hand, in the acidic and nutrient poor water of peat bog, low silicate with lesser seasonal variations was recorded. However, it indicated significant variations between the two annual cycles of the study period ($F_{1, 11} = 6.993$, $P < 0.05$) and registered relatively higher mean during the first year (10.08 ± 2.8 mg/l) in comparison to second year (7.2 ± 3.78 mg/l). All observed values are higher than the reports by Zutshi *et al.*, (1980), Negi and Pant (1983), Vass *et al.*, (1989), Dhendup and Boyd (1994) and Sarwar (1999), Sharma, (2001). Generally a low silicate concentration in the peat bog is identical with some water bodies in Kashmir (Quadri and Yousuf, 1988). Silicate correlated positively with other abiotic parameters including temperature and with dissolved organic matter ($r_2 = 0.509$) and nitrate ($r_2 = 0.579$) in the peat bog. Significant inverse correlation was registered with total hardness ($r_3 = -0.554$) in the paddy-field (Site 3) and with magnesium ($r_2 = -0.635$), chloride ($r_2 = -0.553$) and total dissolved solids ($r_2 = -0.652$) in the peat bog (Site 2).

Dissolved Organic Matter: This comprises fine particulate matter smaller than one μm in size (Moss, 1988) and is derived from various sources including decaying leaves, twigs, decomposed aquatic organisms, excretory bi-products of aquatic organisms and organic matter washed down by rainwater from the catchments areas including exudation from leaves and the bird and insect droppings. The organic matter is the source of nutrition

especially to the protozoan and the filter feeders living in the water (Moss, 1988). During the present study, the monthly quantity of dissolved organic matter varied with a relatively narrow range and low mean at Site 1 (pond) i.e., between 0.24-4.5 mg/l (1.95 ± 1.25 mg/l) and more widely at Site 2 (peat bog) and Site 3 (paddy-field) between 0.9-9.6 mg/l (4.13 ± 3.1 mg/l) and 0.75-11.25 mg/l (2.92 ± 2.46 mg/l) respectively. Significant variations between the sites are indicated by ANOVA ($F_{23, 46} = 5.452$, $P < 0.01$). In the pond, generally higher dissolved organic matter was recorded in early summer (April-June) and in November during both the years, which could be attributed to concentration of the dissolved organic matters during these relatively drier months. Similar effect was observed in the peat bog but various maxima depicted namely, in June (9.6 mg/l) and January (10.72 mg/l) in first year and in May (8.5 mg/l) and January (4.2 mg/l) in the second year were of greater magnitude than in the pond, thereby, depicting distinct bimodal patterns of monthly variations in this water body. In addition, ANOVA indicated significant annual variations in dissolved organic matter content in the peat bog ($F_{1, 11} = 11.740$, $P < 0.01$) and registered higher annual mean during first year (5.38 ± 3.36 mg/l) in comparison to second year (2.87 ± 2.32 mg/l). On the other hand, at Site 3 (paddy-field), dissolved organic matter registered more abrupt fluctuations with maxima during pre-paddy seasons owing to the effect of evaporation as well as during paddy seasons due to the effect of agricultural activities. Further, dissolved organic matter correlated positively with nitrate ($r_2 = 0.701$, $r_3 = 0.674$) at Site 2 and Site 3; with sulphate ($r_1 = 0.413$) at Site 1 and with silicate ($r_2 = 0.509$) and specific conductivity ($r_2 = 0.440$) at Site 2. In addition, significant inverse correlation of dissolved organic matter was computed with potassium ($r_1 = -0.602$), total hardness ($r_1 = -0.501$) and magnesium ($r_1 = -0.515$) at Site 1 and with total dissolved solids ($r_2 = -0.566$) at Site 2.

Total Dissolved Solids: These are comprised mainly of inorganic salts formed by the association of carbonate, bicarbonate, chloride, sulphate and nitrate with Na, K, Ca etc. and also small organic matter. In the present investigation, total dissolved solids was found to be low at all sites and varied between 0.24-0.85 mg/l (0.49 ± 0.17 mg/l), 0.22-0.85 mg/l (0.54 ± 0.17 mg/l) and 0.24-0.60 mg/l (0.40 ± 0.11 mg/l) at Sites 1-3 respectively. Low dissolved solids at these sites corresponded with low ionic concentrations in general. ANOVA indicated its significant variations between three sampled sites ($F_{23, 46} = 5.151$, P

< 0.05). Total dissolved solids in the pond and the peat bog exhibited higher values during winter and early summer and generally a low during rainy season due to dilution effect of the later. However, it increased gradually towards the end of monsoon, apparently as a result of greater decomposition. In the paddy-field, agricultural practices influenced its fluctuation trend and registered bimodal and multimodal patterns during the first and the second year of study respectively. Maxima in June (0.58 mg/l) in first year and the peak in May (0.60 mg/l) in second year coincided with the beginning of agricultural activities in the paddy-field, thereby, causing leaching out of the inorganic salts into the surface water which contributed to the increase in dissolved solids. Further, secondary maxima was also exhibited in the post-paddy seasons due to evaporation and concentration of the dissolved solids in this ephemeral ecosystem. Total dissolved solids exhibited significant positive relationship with calcium in the peat bog ($r_2 = 0.442$) and with phosphate in the pond and the paddy-field ($r_1 = 0.421$, $r_3 = 0.441$). On the other hand, inverse relationship was noticed with magnesium ($r_2 = -0.703$) and rainfall ($r_2 = -0.652$) in the peat bog and chloride ($r_2 = -0.494$, $r_3 = -0.432$) in the latter as well as in the paddy-field.

II. BIOTIC FACTORS

Net Plankton: Net plankton in the three sampled biotopes viz. Site 1 (pond), Site 2 (peat bog) and Site 3 (paddy-field) appeared to be diversified i.e., Site 3 (89 species) > Site 1 (76 species) = Site 2 (76 species) and recorded 120 species including 47 species of phytoplankton and 73 species of zooplankton in all. ANOVA indicated significant variations in species richness of net plankton between sites ($F_{2, 46} = 14.093$, $P < 0.01$) but insignificant variations between months. Monthly species richness of net plankton exhibited wide range at Site 2 (peat bog) i.e., between 17-45 species (30 ± 7 species) followed by Site 1 (pond), which in turn, ranged between 18-36 species (27 ± 5 species). On the other hand, a relatively narrow range and higher mean of 27-42 species (35 ± 4 species) was recorded at Site 3 (paddy-field). The recorded values are identical to the report of Sharma and Lyngdoh (2003) and higher than the results of Bhattacharya and Saha (1986), Alfred and Thapa (1995), Sharma (1995) and Sharma and Lyngskor (2003). In the pond (Site 1), bimodal pattern of net plankton species richness was depicted during first year with peak (36 species) in June and secondary maxima in December (32 species). On

the other hand, a unimodal pattern was registered during second year with maxima in July (36 species).

Further, in the pond, generally higher species richness was seen between May-July (18-36 species) during both annual cycles with generally low richness during winter. However in the peat bog, low species richness of net plankton in general, was owing to its acidic and nutrient poor characteristic (Horne and Goldman, 1994). In this water body, broadly bimodal patterns of their temporal variations were depicted during both annual cycles of study period. During the first year, primary maxima was observed in May (39 species) and secondary in December (29 species), while in the second year, peak richness was registered in July (45 species) and was generally low during late monsoon. The latter could be apparently owing to greater rate of decomposition, thereby, further causing a decrease in pH (5.87-6.45) and diminution of dissolved oxygen (2.0-4.0 mg/l). On the contrary, paddy-field (Site 3) depicted highest species richness among all three sites, which could be attributed to its ephemeral nature and growth of the paddy. It depicted a bimodal pattern of monthly variations in first year with peak in March (42 species) during the first year followed by minima in June coinciding with the ploughing activities, which could have caused adverse condition temporarily due to increased turbidity. However, net plankton richness increased during the paddy season in both the annual cycles owing to development of periphyton as well as the epiphytic organisms.

Quantitative abundance of net plankton at Sites 1-3 exhibited considerable temporal variations and ranged between 93-1114 n/l (286 ± 227 n/l), 93-692 n/l (245 ± 136 n/l) and 75-663 n/l (247 ± 138 n/l) respectively. The recorded ranges of net plankton densities at all study sites were higher than reports of Sharma (1995), Jyrwa (1996) and Sharma and Wanswett (1999). The peak abundance of net plankton was registered during spring in pond (Site 1), during monsoon in peat bog (Site 2) and during winter in the paddy-field (Site 3). Among the three sites, pond (Site 1) showed wider range of net plankton density even though mean values at all sites were nearly identical. This was due to higher abundance of net plankton in the pond during the first year owing to a high abundance of copepods (950 n/l), which is also affirmed by a significant positive correlation between them ($r_1 = 0.957$). Further at this site, bimodal patterns of monthly variations in net plankton abundance were observed with a distinct peak (1114 n/l) in April during first year and relatively lower maxima in succeeding year during March (339 n/l). Similarly, secondary maxima were

registered in November (310 n/l) in first year and December-January (289 n/l) in the second year. Therefore, higher density of net plankton was seen in relatively dry months during the pre- and post-monsoon periods coinciding with higher concentration of the nutrients in the pond. This fact was also indicated by a direct correlation with phosphate ($r_1 = 0.481$) and TDS ($r_1 = 0.524$) at this site.

Net plankton abundance at Site 2 (peat bog) depicted significant variations between two years ($F_{1, 11} = 4.812$, $P < 0.05$) and registered wider range and higher mean during the first annual cycle. It depicted a broadly bimodal pattern of monthly variations with peak in mid-monsoon i.e., in August in first year (692 n/l) and primary maxima of relatively lower magnitude in July (280 n/l) in second year and seemed to be influenced by the rainfall as also affirmed by significant positive correlations with the latter ($r_2 = 0.579$). Further, secondary maxima of lower magnitude were depicted in early winter (December) of both annual cycles (322 n/l and 241 n/l respectively) apparently owing to relatively lesser decomposition at low temperature during this period. However in the paddy-field (Site 3), a trimodal pattern of monthly variations were seen during both annual cycles of study period. Generally higher abundance of net plankton was observed during the period of active growth of paddy owing to periphyton and epiphytic abundance. An increasing trend in the net plankton abundance during the paddy season also concurred with the earlier reports of Fernando (1995) and Jyrwa (1996), which is also attributed to favourable conditions such as high temperature and abundance of nutrients (Pont, 1977 and Heckman 1979). ANOVA indicated significant variations of net plankton abundance between two years of study period ($F_{1, 11} = 5.032$, $P < 0.05$). Its maxima was recorded in October (338 n/l) of the first year and in July of the second year (274 n/l). However, a distinct peak was depicted in December (663 n/l) during the second year owing to a bloom of *Nostoc* sp. (500 n/l) indicating more erratic conditions in this ephemeral and frequently intervened ecosystem.

The present study indicated numerical dominance of phytoplankton, as they comprised between 3.9-85.5% ($48.0 \pm 27.3\%$), 35.3-91.0% ($68.5 \pm 12.0\%$) and 48.5-92.5% ($67.8 \pm 12.2\%$) of net plankton at Sites 1-3 respectively. However at Site 1 (pond), phytoplankton distinctly dominated between July-December (51.1-85.5%) in first year and between September-January (66.9-85.1%) in second year and the later was dominated by zooplankton during the late winter to early summer. On the other hand, at Site 2 (peat bog) and Site 3 (paddy-field), they indicated numerical predominance throughout the study

period except in March 2001 (35.2%) at Site 2 and April (48.52 %) and July (48.91 %) 2001 at Site 3. Further, percentage composition of phytoplankton at Site 1 (pond) was lower than the reports of Mathew (1975), Yadava *et al.*, (1987), Sharma (1995) and Prakash (2001), while it broadly corresponded with the stated reports at Site 2 (peat bog) and Site 3 (paddy-field). Quantitative importance of phytoplankton in the peat bog and the paddy-field is affirmed by their highly significant positive correlations with net plankton ($r_2 = 0.989$, $r_3 = 0.981$). On the other hand, zooplankton comprised an important component of net plankton in the pond and contributed 14.5 - 96.1% ($51.9 \pm 27.3\%$) with maximum percentage contribution during April in first year. Further, zooplankton was numerically predominant in 13 out of 24 monthly samples. The stated impact was further confirmed by a highly significant positive correlation between net plankton and zooplankton in the pond ($r_1 = 0.955$). However at Site 2 and Site 3, percentage composition of zooplankton varied less widely and recorded lower mean values than in the pond i.e., between 10.4-64.7% ($31.5 \pm 12.0\%$) and 7.5-51.5% ($32.0 \pm 12.2\%$) respectively. Thus numerical dominance of zooplankton in the pond is in contrast to the reports of Nasar (1977), Mathew (1975), Yadava *et al.*, (1987), Sharma (1995), Alfred and Thapa (1995), Lyngdoh (1998) and Lakiang (1998). However, at Site 2 (peat bog) as well as at Site 3 (paddy-field), zooplankton comprised a sub-dominant group and this concurred with the cited reports. Further, in the pond, phytoplankton and zooplankton abundance showed seasonal succession. During both the annual cycles of the study period, maxima of zooplankton abundance in early summer was succeeded by the maxima of phytoplankton during the late monsoon. However, no such conspicuous relationship was recorded in the other two sites.

Phytoplankton: They appeared to be moderately speciose (47 species) and belonged to Chlorophyceae (20 species) > Bacillariophyceae (15 species) > Cyanophyceae (6 species) > Euglenophyceae (3 species) > Dinophyceae (2 species) > Chrysophyceae (1 species) in the stated order of their qualitative significance. Highest number of phytoplankton species were observed in the paddy-field (35 species) followed by relatively lesser number in peat bog (27 species) and least in the pond (26 species), thereby, indicated variations in ecosystem heterogeneity. The recorded overall richness of phytoplankton is relatively higher than the report of Lyngdoh (2002) and is substantially higher than Sharma (1995) from Meghalaya.

However, it is lower than the reports by Kaul and Pandit (1981, 1982), Pandit (1999) and Sarwar (1999) from some lakes and wetlands of Kashmir.

ANOVA indicated significant variations in phytoplankton richness between the sites ($F_{2, 46} = 22.078$, $P > 0.01$). Monthly species richness in the pond (Site 1) ranged between 6-14 species (10 ± 2 species), varied with a trimodal pattern and registered its maxima generally during summer. The peak richness was recorded in July as well as September, while maxima were also recorded in December-January during the first year (13 species each) while maxima of equal values (12 species each) were recorded in March, July and December during the second year. In the peat bog, their richness ranged between 5-16 species (10 ± 3 species) during the study period and registered broadly bimodal pattern of monthly variations. While primary maxima in the first year was noticed in December (14 species), the peak was recorded in July during the second year. Generally low richness (5-11 species) was noticed from late winter to early summer during both annual cycles. On the other hand, in the paddy-field phytoplankton richness ranged more widely with higher mean i.e., 8-18 species (14 ± 3 species). Further, a wider range of 8-16 species was recorded during first year in comparison to narrow range of 13-18 species during the second year in the paddy-field. Monthly variations in richness depicted a multimodal pattern with maxima of relatively higher magnitudes during early summer in both the annual cycles i.e. in March (17 species) in first year and May (18 species) during the second year. This finding is contrary to the reports of Jyrwa (1996) from Ummolong paddy-field in Meghalaya where maxima was reported during the paddy season. In addition, greater species richness of phytoplankton was observed during warmer months at all sites with maximum species during May of second year (18 species) at Site 3 (paddy-field), during July (16 species) of second year at Site 2 (peat bog) and during September of first year (14 species) at Site 1 (pond).

Phytoplankton indicated qualitative dominance of Bacillariophyceae > Chlorophyceae at Site 1 (pond), which concurred with the results of Sarwar (1999) from Anchar Lake in Kashmir. On the contrary, Site 2 (peat bog) and Site 3 (paddy-field) exhibited Chlorophyceae > Bacillariophyceae, which, in turn, concurred with most of the earlier reports (Kaul *et al.*, 1978; Pandit and Kaul, 1982; Bhattacharya, 1980; Bhattacharya and Saha, 1990; Sharma, 1995; Alfred and Thapa, 1995; Das *et al.*, 1996; and Sharma and Lyngskor, 2003; Sharma and Lyngdoh, 2003). Further at Site 1 (pond), only four groups of

phytoplankton were recorded with the dominance spectrum of Bacillariophyceae (12 species) > Chlorophyceae (10 species) > Cyanophyceae (3 species) > Euglenophyceae (1 species) while five groups at Site 2 (peat bog) exhibited Chlorophyceae (11 species) > Bacillariophyceae (7 species) > Cyanophyceae (5 species) > Euglenophyceae = Dinophyceae (2 species). The paddy-field (Site 3), on the other hand, represented maximum groups (six families) of phytoplankton and exhibited Chlorophyceae (15 species) > Bacillariophyceae (11 species) > Cyanophyceae (4 species) > Euglenophyceae (3 species) > Chrysophyceae = Dinophyceae (1 species).

Community similarities computed between three sites indicated least phytoplankton similarity (60%) between pond and paddy-field, thereby, indicating greater heterogeneity between their communities. This is followed by pond and peat bog (64%) and maximum similarity between peat bog and the paddy-field (70%), which in turn, indicated greater homogeneity between the latter sites. On the other hand, month-wise percentage similarities between phytoplankton communities during the two annual cycles in each study site ranged between 21.1%-100.0% at Site 1 (pond), 13.3%-95.2% at Site 2 (peat bog) and 24.0-85.7% at Site 3 (paddy-field), thereby, indicating notable temporal variations in their community structure. The recorded values in Sites 1 (pond) and 2 (peat bog) depicted wider ranges than the reports of Sharma (1995), but in Site 3 (paddy-field) the range broadly concurred with the cited report. However, at all sites, percentage similarity ranged less widely than the reports by Sharma and Lyngdoh (2003). Further, relatively less wide temporal variation in their community structure was observed during paddy season in the paddy-field (44.4-85.7%), which, in turn, concurred with the report of Jyrwa (1996). Maximum percentage similarity was recorded between September and October 2000 at Sites 1 and 3, and between the samples of April and May 2001 at Site 2. Similarly, minimum similarity was recorded between November 2000 and April 2001 at Site 1, between April 2000 and February 2001 at Site 2 and between March and April 2000 at Site 3, thereby, indicating notable differences in the species composition of phytoplankton during dry months at all sites. Besides, the percentage similarity was > 80% in seven instances at Site 1 (pond) and in 14 instances at Site 2 (peat bog). However, less than 30% similarity was observed in five and six instances at Sites 1 and 3 respectively but in 11 instances at Site 2 thereby depicting wider variations in community structure in the peat bog among three studied biotopes.

ANOVA indicated significant variations in phytoplankton abundance between study sites ($F_{2, 46} = 3.225$, $P < 0.05$). The quantitative abundance of phytoplankton ranged relatively less widely between 38-265 n/l (106 ± 72 n/l) at Site 1 (pond) depicting broadly unimodal patterns of monthly fluctuation with single distinct maxima each year i.e., during autumn (November 2001) and early winter (December 2002) respectively. This pattern recorded in the pond concurred with the report of Kant and Kachroo (1974). While higher phytoplankton abundance during colder months observed in the pond concurred with reports of Saha *et al.*, (1971) and Sharma (1995). The later aspect is also affirmed by an inverse relationship with water temperature ($r_1 = -0.486$). Further, low density during rainy seasons in this pond is confirmed by an inverse relationship with the rainfall ($r_1 = -0.574$).

However at Site 2 (peat bog) and Site 3 (paddy-field), phytoplankton abundance ranged more widely i.e., between 55-630 n/l (179 ± 136 n/l) and 43-613 n/l (180 ± 139 n/l) respectively. The recorded ranges and mean values in the peat bog and the paddy-field are broadly identical to the reports by Sharma and Lyngdoh (2003) but higher than the reports of Sharma (1995) and Jyrwa (1996). On the other hand, the recorded values are significantly lower than the reports of Vyas *et al.*, (1988) and Pandit (1999). In addition, in the peat bog (Site 2), ANOVA indicated significant variations of phytoplankton abundance between two years ($F_{1, 11} = 5.329$, $P < 0.05$) and registered wider ranges (59-630 n/l) and relatively higher mean (229 ± 177 n/l) during the first year against lower value of 55-178 (129 ± 42 n/l) during the second year. The variation was apparently owing to relatively lesser annual rainfall during the second year of study, the impact of which is indicated by their positive relationship ($r_2 = 0.535$). In addition, higher density was seen during monsoon with peak in August (630 n/l) during the first year and maxima in July (178 n/l) during the second year. The above results in the peat bog concurred with the reports of Zutshi *et al.*, (1980).

On the other hand, in the paddy-field, a broadly bimodal pattern of temporal variations was recorded during both annual cycles of study period and showed higher density during autumn and early winter (October-January). Maxima were recorded in October (268 n/l) and January (218 n/l) during the first year and peak density in December (613 n/l) during the succeeding year. However, secondary maxima of second year was registered during early paddy season in May (173 n/l). Further, phytoplankton abundance decreased during the early phase of paddy seasons (May-June 2000 and June-July 2001),

which indicated adverse impact of increased turbidity caused by ploughing (Fernando, 1993) during this period. Generally higher density in winter is affirmed by an inverse relationship with water temperature ($r_3 = -0.748$) in this paddy-field.

During the present study phytoplankton communities depicted low to moderate species diversity computed *vide* Shannon's index (H') and ranged between 1.257-2.407 (1.878 ± 0.445) in the pond, 0.961-2.882 (2.046 ± 0.589) in the peat bog and 0.851-2.394 (1.916 ± 0.456) in the paddy-field. Similarly, Menhinick's index (D_{mn}) varied with their narrow ranges and lower mean values i.e., between 0.553-1.930 (1.239 ± 0.460), 0.359-1.483 (0.820 ± 0.262) and 0.646-1.913 (1.178 ± 0.353) at three sites respectively. The present observations broadly resembled with findings in Meghalaya (Sharma, 1995; Jyrwa, 1996; Lyngskor, 1997; Lakiang, 1998 and Lyngdoh, 1998). A narrow range of diversity was recorded in the pond (Site 1) with relatively higher diversity in pre-monsoon and early monsoon periods. It depicted peak diversity during first year as well as maxima in second year of the study in the month of July, while low diversity of phytoplankton was noticed from October-December during both annual cycles of study period in this ecosystem.

On the other hand, peat bog indicated relatively higher diversity among three study sites and depicted broadly bimodal pattern of monthly fluctuation with peak in May and primary maxima in July during two years respectively, thereby indicating higher species diversity during early summer. While the diversity was generally high during the first year, it showed more fluctuations during the second year and depicted low values between February-March as well as between September-October. Relatively higher diversity of phytoplankton in the peat bog also indicated low fertility of this ecosystem (Margalef, 1964, 1968) in comparison to other two study sites. On the other hand, Site 3 (paddy-field) depicted a multimodal pattern of monthly variations with peak in March during first year and other higher maxima of two years coincided in the months of May and August. Therefore, relatively higher species diversity was seen during pre-paddy and post-paddy seasons during both the annual cycles. However, diversity was particularly low between June-July (1.57-1.83) as well as in October (minima) during first year coinciding with plantation and harvest activities respectively, thereby indicating impact of agricultural practices on the phytoplankton diversity in this ecosystem. Besides, low diversity during the end of the study period i.e., November-December 2001 (0.85-1.52) is apparently owing to predominance of *Nostoc* sp., which showed its bloom during these months. Incidence of

such a low diversity during an algal bloom was also reported by Kelly *et al.*, (1978). The diversity of phytoplankton showed direct significant correlation with evenness ($r_2 = 0.896$, $r_3 = 0.928$) in the peat bog as well as the paddy-field thereby indicating higher diversity when there is more equitable abundance of different species. Further, diversity showed direct significant correlation with species richness of phytoplankton ($r_1 = 0.478$) at Site 1 (pond), which is concurrent with the reports of Pielou (1975). However, lack of direct relationship of diversity with species richness in other two water bodies was in agreement with Saeger and Hasler (1969) and Singh *et al.* (1982). Further it showed inverse relationship with dominance at all sites ($r_1 = -0.847$, $r_2 = -0.755$, $r_3 = -0.922$) as well as with phytoplankton abundance at Sites 1 and 3 ($r_1 = -0.760$, $r_3 = -0.718$), which in turn, broadly concurred with the report of Singh *et al.* (1982).

Phytoplankton dominance at all sites was generally low and ranged with least values at Site 1 (pond) i.e., between 0.098-0.496 (0.219 ± 0.111). On the other hand, it registered wider range and relatively higher mean values in the peat bog i.e., between 0.128-0.666 (0.290 ± 0.145) and between 0.039-0.671 (0.245 ± 0.160) in the paddy-field *vide* Simpson's index (λ). The recorded values were broadly identical to reports of Singh *et al.* (1982) from some lakes of Kumaon Hills but higher than the reports of Sharma and Lyngdoh (2003) from Umiam Reservoir in Meghalaya. Further in the pond (Site 1), a unimodal pattern of temporal variations of phytoplankton dominance was registered with relatively wider range in the first annual cycle of the study period. A low dominance was recorded for a longer duration between February-August during both the years and maxima were registered in December in first year and January in the second year, which broadly coincided with higher phytoplankton abundance at this site. This fact is also affirmed by a positive correlation with the abundance ($r_1 = 0.809$). In addition, low dominance with relatively lesser fluctuations during the study period indicated lack of any quantitatively dominant phytoplankton species (Mc Naughton, 1967) in this water body.

In the peat bog (Site 2), bimodal patterns of monthly variations were observed with secondary maxima in March and primary maxima in December during first year. Similarly, peak dominance was recorded in February and a secondary maxima in October during the second year, thereby, depicting higher dominance in late autumn-winter. An overall low dominance between May-September in first year and between April-July in second year coincided with higher species richness of phytoplankton at this site. This fact was also

affirmed by an inverse relationship between the dominance and species richness ($r_2 = -0.432$). On the other hand, at Site 3 (paddy-field), a trimodal pattern with a narrow range (0.110-0.492) of monthly fluctuations in the first year and a unimodal pattern with relatively wider range (0.039-0.671) in the second year were recorded. Peak dominance in the paddy-field coincided with *Nostoc* sp. bloom during December of the second year. Dominance indicated inverse relationship with species richness ($r_3 = -0.539$) and positive correlation with phytoplankton abundance ($r_3 = 0.720$) in the paddy-field.

High evenness (E_1) of phytoplankton was computed during the present investigation and fluctuated with wide ranges i.e., between 0.342-1.199 (0.825 ± 0.230) in the pond, 0.536-1.386 (0.908 ± 0.24) in the peat bog and 0.307-0.938 (0.732 ± 0.167) in the paddy-field. The recorded values at all sites are marginally lower than the reports of Sharma and Lyngdoh (2003) but higher than the reports by Wanswett (2001). Further high evenness at all sites indicated greater equitability of species abundance in the community (Washington, 1984). In addition, evenness fluctuated with multimodal pattern of variations at Site 1 (pond) with a relatively wider range during the second year. Generally higher evenness was seen in spring as well as mid-monsoon period. Monthly variations in evenness in this water body broadly corresponded with the species diversity variations and indicated by a significant positive correlation with the later ($r_1 = 0.896$). On the other hand, peat bog exhibited consistently high evenness between March-November in first year resulting into peak in the later month. However, in the second year evenness was relatively low (0.739 ± 0.118) with smaller maxima in July, which corresponded with the maxima of species diversity of that year. In the paddy-field (Site 3), in turn, low mean evenness of phytoplankton was recorded and varied within narrow range during the study period. Relatively higher values were observed in May and August in first year, which also coincided with higher species diversity. A significant positive correlation with later ($r_3 = 0.928$) and inverse relationship with dominance ($r_3 = -0.940$) was observed at this site. It also depicted an inverse relationship with phytoplankton abundance ($r_3 = -0.842$).

Of recorded phytoplankton groups, the Chlorophyceae ranged between 1-7 species at Site 1 (pond), 1-6 species at Site 2 (peat bog) and 2-9 species at Site 3 (paddy-field) and recorded highest number of species of these green algae in the paddy-field (15 species). The recorded Chlorophyceae species richness was identical to the reports of Sharma and Lyngdoh (2003) but lower than that of Singh *et al.*, (1982), Pandit (1999) and Sarwar

(1999). ANOVA indicated significant variations in species richness of Chlorophyceae between sites ($F_{2, 46} = 7.937$, $P > 0.01$). It registered higher species richness during summer (May-July) at Site 1 (pond) as well as Site 2 (peat bog) with peak depicted in June in first year at both sites. However, at Site 3 (paddy-field), it followed a broadly bimodal pattern with maxima in post-paddy season (January of first year and December of second year) as well as paddy seasons (August) during both annual cycles of the study period. In addition, significant annual variation in species richness of green algae was seen in the paddy-field ($F_{1, 11} = 8.830$, $P > 0.01$), which registered relatively higher species richness during second year (4-9 species) in comparison to the preceding year (2-7 species).

Chlorophyceae included 8 species of desmids in all, which represented about 40% of the green algae. Presence of relatively high number of desmids could be attributed to low bicarbonate and calcium contents in these waters (Strom, 1921; Hutchinson *et al.*, 1932; Cole, 1957; Wade, 1957; Tassigny, 1971; Woelkerling and Gough, 1976; Moss, 1988). In addition, it included four taxa of filamentous algae, of which *Spirogyra* sp. was common at all sites and occurred during all 24 monthly collections at Site 2 (peat bog) and in 19 and 18 months at Site 1 (pond) and Site 3 (paddy-field) respectively. Further, *Volvox* sp. was regular taxa at Site 1, *Cosmarium* sp. at Site 2 and *Closterium* sp. at Site 3 and occurred in most of their monthly collections. On the other hand, *Staurastrum* sp. at Site 1 and *Radiococcus* sp. at Site 3 showed rare occurrence as they were observed only in one of their monthly collections each during the study period. While *Mougeotia* sp. and *Staurastrum* sp. were recorded only in the pond, *Pleurodiscus* sp. was recorded only at Site 2. On the other hand, five species of Chlorophyceae viz. *Oedogonium* sp., *Radiococcus* sp., *Scenedesmus quadricaudata*, *Tetraspora* sp. and *Zygnema* sp. were recorded only in the paddy-field (Site 3).

Quantitative abundance of Chlorophyceae exhibited significant variations among three study sites ($F_{2, 46} = 19.093$, $P > 0.01$) and registered narrow ranges at Site 1 (pond) and Site 3 (paddy-field) i.e., between 4-59 n/l (21 ± 12 n/l) and 4-88 n/l (35 ± 23 n/l) respectively. The recorded values in both sites were lower than the reports of Sharma (1995), Jyrwa (1996), Lyngdoh (1998), Wanswett (2001) and Lyngdoh (2002). In addition, pond depicted less monthly variations with relatively higher abundance in the pre- and post monsoon periods, which coincided with greater concentration of the nutrients during these dry months. This fact is also indicated by direct significant correlations with phosphate (r_1

= 0.520) and total dissolved solids ($r_1 = 0.449$) in this water body. Percentage composition of green algae ranged between 3.4-67.8% in the pond and was a dominant group for five months viz. March and April in first year (67.8 and 67.4% respectively) and between April-June (57.4-63.2%) in second year. On the other hand, paddy-field exhibited relatively wider monthly variations of this group and depicted broadly bimodal patterns with generally higher abundance during the pre-paddy and early paddy seasons. Maxima of relatively lower magnitude were recorded during first year in March (43 n/l) and in August (51 n/l) and of higher magnitude during second year in February (81 n/l) and May (88 n/l). Low abundance was seen during the later phase of paddy season during both the years apparently owing to reduced water level in this ephemeral water body. Similarly, Chlorophyceae comprised between 5.2-60.5% of phytoplankton and was numerically dominant in March of both the years (54.4% and 56.1% respectively) and during May (50.9%) and June (60.5%) in second year.

However at Site 2 (peat bog), it ranged widely with higher mean between 15-274 n/l (90 ± 63 n/l) and was therefore, a predominant group of phytoplankton. It is supported by a highly significant positive correlation with the latter ($r_2 = 0.874$) at this site. Further, significant variations in density of the green algae was seen at this site ($F_{1, 11} = 4.668$, $P < 0.05$) and recorded wider range (15-274 n/l) and a higher mean (107 ± 84 n/l) during first year than the succeeding one, which in turn, ranged between 40-109 n/l (74 ± 27 n/l). During both the annual cycles its population density maxima was recorded during monsoon with a distinct peak in August of first year and maxima in September of second year, which was followed by a decline from October-December. Abundance, therefore, was directly influenced by water temperature ($r_2 = 0.548$) and rainfall ($r_2 = 0.548$). Further, in the peat bog, Chlorophyceae comprised between 5.6-82.7% of phytoplankton abundance and was dominant during almost all sampled months except August (43.5%) and December (5.6%) during the first year.

Of the recorded taxa of this group, the green filamentous algae, *Spirogyra* sp. was recorded at all sites and recorded maximum abundance in the peat bog (10-158 n/l). It varied with bimodal pattern of monthly variations and depicted peak (158 n/l) in the month of August during first year and primary maxima of second year in September (102 n/l). Similarly, maxima were also recorded in April (75 n/l) and May (54 n/l) during the two annual cycles respectively. The former along with *Ulothrix* sp. (0-153 n/l) contributed

significantly to Chlorophyceae in the peat bog. In the pond, *Spirogyra* sp. (0-32 n/l) along with *Mougeotia* sp. (0-18 n/l) was quantitatively important filamentous algae and occurred mostly in pre-monsoon and post-monsoon periods. On the other hand, in the paddy-field (Site 3), the former was the only quantitatively important (0-37 n/l) filamentous taxa and was recorded in greater abundance during the period of active growth of paddy (June-August). In addition, desmids were recorded in greater abundance at all sites during early summer. In the paddy-field, desmids ranged between 0-39 n/l and comprised significant percentage contribution of 0.0-86.0% ($37.0 \pm 5.6\%$) to Chlorophyceae abundance. *Closterium* sp. (0-20 n/l) and *Cosmarium* sp. (0-28 n/l) were quantitatively important species at this site. Higher abundance of desmids was generally observed during pre-paddy as well as post-paddy seasons. Similarly, in the pond, *Micrasterias* sp. (0-18 n/l) and *Desmidium* sp. (0-8 n/l) were the important desmids and all combinedly ranged between 0-17 n/l and comprised 0.0-58.0% ($23.0 \pm 15.0\%$) of total Chlorophyceae. On the other hand, in the peat bog, monthly abundance of desmids ranged between 0-49 n/l with percentage contribution of 0.0-42.0% ($16 \pm 8.0\%$) to the Chlorophyceae. *Cosmarium* sp. (0-25 n/l) and *Desmidium* sp. (0-20 n/l) were found in relatively higher abundance in this ecosystem. Among the other green algae, *Pediastrum* sp. (0-7 n/l) and *Volvox* sp. (0-9 n/l) occurred regularly in the pond. In the paddy-field, *Scenedesmus quadricaudata* (0-54 n/l), *Pediastrum* sp. (0-14 n/l) and *Volvox* sp. (0-20 n/l) were found in relatively greater abundance.

Of the recorded abiotic factors, the Chlorophyceae registered direct correlation with total alkalinity ($r_3 = 0.525$), potassium ($r_3 = 0.546$) and chloride ($r_3 = 0.651$) at Site 3 (paddy-field). On the other hand, inverse relationship of this group was observed with pH ($r_1 = -0.515$) at Site 1 (pond) and with specific conductivity ($r_2 = -0.460$) and dissolved oxygen ($r_2 = -0.418$) at Site 2 (peat bog).

The Bacillariophyceae (12 species) was most important qualitative group of phytoplankton in the pond (Site 1). Their monthly richness ranged between 3-8 species and was relatively higher during the post-monsoon period. Similarly, 11 diatom species were recorded in the paddy-field (Site 3); their richness ranged between 3-8 species and recorded relatively higher number during pre-paddy as well as post-paddy seasons. On the other hand, in the peat bog (Site 2), low species richness (7 species) of diatoms was seen and ranged between 1-5 species during the study period. ANOVA indicated significant

variations in species richness of diatoms between the sites ($F_{2, 46} = 30.358$, $P < 0.01$). Recorded species richness of the diatoms is broadly identical to Singh *et al.*, (1982) from some lakes of Kumaon Himalayas and marginally higher than Sharma (1995) and Sharma and Lyngdoh (2003). On the other hand, it is substantially lower than the reports from some other western Himalayan water bodies (Kaul *et al.*, 1978; Zutshi *et al.*, 1980; Zutshi and Wanganeo, 1984; Pandit, 1999 and Sarwar, 1999). Among the diatoms, *Caloneis* sp., *Cymbella* sp., *Eunotia* sp., *Fragilaria* sp. and *Synedra* sp. showed common occurrence at all three sites. Further, *Navicula* sp. at Sites 1 (pond) and 2 (Peat bog) and *Pinnularia* sp. at Site 2 were dominant both qualitatively and quantitatively and occurred regularly. The occurrence of former species coincided with the reports by Jyrwa (1996), Pandit (1999) and Sarwar (1999). On the other hand, *Diatoma* sp. at Site 1, *Cymbella* sp. and *Gyrisigma* sp. at Sites 2 and 3 respectively showed rare occurrence. Similarly, *Amphora* sp., *Frustulia* sp., *Neidium* sp. and *Tabellaria* sp. were observed only in the pond, while *Pleurodiscus* sp. was seen only in the peat bog. Only the paddy-field recorded *Asterionella* sp., *Gyrisigma* sp. and *Stauroneis* sp.

Regarding the abundance of the Bacillariophyceae, ANOVA indicated significant variations between the three sites ($F_{2, 46} = 9.610$, $P < 0.01$). It exhibited wider ranges in the paddy-field (Site 3) and the peat bog (Site 2) with higher mean in the former i.e., between 12-237 n/l (83 ± 53 n/l) and 2-226 n/l (36 ± 43 n/l) respectively. On the other hand, it varied with relatively narrow range i.e., between 12-103 n/l (46 ± 25 n/l in the pond (Site 1)). Recorded diatom density at all sites is higher than the reports of Goel *et al.*, (1988), Alfred and Thapa (1995), Jyrwa (1996), Das *et al.*, (1996) and Sharma and Lyngskor (2003). Further, in the pond as well as in the paddy-field, diatoms formed most dominant group of phytoplankton and it was sub-dominant in the peat bog. Important quantitative role of this group in the former two biotopes is further affirmed by their positive correlation with phytoplankton ($r_1 = 0.786$ and $r_3 = 0.928$).

Monthly variations of abundance of Bacillariophyceae depicted bimodal pattern at Site 1 (pond); they registered maxima in July (76 n/l) and November (98 n/l) during the first year and a distinct peak in December (103 n/l) during the second year. Percentage composition of this group at this site ranged between 19.3-81.7% (47.8 ± 16.2 %) and was numerically dominant in February (50.5%) and May-September (50.8-81.7%) during first year and January-March (44.4-60%) and July-September (49.5-75%) during the succeeding

year. However in the peat bog, this group followed unimodal pattern and depicted a distinct peak in December (226 n/l) during the first year. The recorded low diatom density during the pre-monsoon period is apparently due to greater decomposition and sedimentation during these relatively dry and warm months. Their percentage contribution to phytoplankton at this site ranged between 1.8-84.3% ($21.0 \pm 15.7\%$) and was dominant only in December (84.3%) during the first year. On the other hand, in the paddy-field, a broadly bimodal pattern was recorded with a distinct peak in October (237 n/l) in first year and the primary maxima (99 n/l) in second year also occurred in the same month. Generally higher abundance of diatoms occurred between late paddy seasons to post paddy season (September-February). It contributed significantly between 10.3-88.4% ($52.4 \pm 23.6\%$) and dominated over other groups for a longer duration (15 out of 24 months) i.e., between May 2000-February 2001 (40-2-88.4%) and in April (55.7%) as well as between July-October 2001 (59.7-73.9%). Broadly, the recorded winter maxima of Bacillariophyceae at all sites coincided with the report of Agbeti *et al.* (1997).

Among the documented members of this group at Site 1 (pond), *Navicula* sp. (2-55 n/l), *Neidium* sp. (0-70 n/l), *Fragilaria* sp. (0-25 n/l), *Pinnularia* sp. (0-15 n/l) and *Cymbella* sp. (0-12 n/l) were quantitatively important species. Of these, *Navicula* sp. was seen in greater abundance during autumn (September-November). Similarly in the peat bog (Site 2), three diatoms of quantitative importance included, a widely ranging *Pinnularia* sp. (0-210 n/l) and *Navicula* sp. (0-30 n/l), both of which occurred in greater abundance during winter. In addition, *Fragilaria* sp. (0-18 n/l) was observed mainly during summer. On the other hand, in the paddy-field (Site 3), *Navicula* sp. ranged more widely between 5-170 n/l and depicted higher density in winter, as in the peat bog, and *Asterionella* sp. (0-20 n/l) during late paddy season. Other diatoms of quantitative importance in the paddy-field included *Pinnularia* sp. (0-25 n/l), *Cymbella* sp. (0-19 n/l), *Fragilaria* sp. (0-51 n/l) and *Synedra* sp. (0-17 n/l), which were recorded occasionally.

Cyanophyceae, comprised six taxa in all and ranged between 0-2 species at Site 1 (pond) 1-3 species at Site 2 (peat bog) and 0-3 species at Site 3 (paddy-field) and did not depict significant variations among the three sites. Relatively low species richness of the blue-green algae in the present study broadly concurred with reports of Zutshi *et al.*, (1980) and Singh *et al.*, (1982). However, the recorded richness was marginally higher than the reports of Khan and Zutshi, 1980, Jyrwa (1996) and Sharma and Lyngdoh (2003), while it

was significantly lower than Kaul *et al.*, (1978), Pandit (1999) and Sarwar (1999). Among the recorded blue green algae, *Oscillatoria* sp. was observed during majority of monthly collections, while *Microcystis* sp. exhibited rare occurrence at all sites. Among other species, *Anabaena* sp. was recorded during early summer (March-May) and *Lyngbya* sp. during monsoon (July-September) in the peat bog. Similarly, *Nostoc* sp. was recorded only in the paddy-field during the post-paddy season.

Cyanophyceae constituted third quantitatively important group at all sites. In the pond (Site 1), it fluctuated with a comparatively narrow range between 0-184 n/l (38 ± 56 n/l) and depicted its peak density in December during first year while maxima of second year was registered in January (125 n/l). Low abundance of the blue-green algae in late winter and during monsoon was also affirmed by significant inverse relationship with water temperature ($r_1 = -0.444$) and rainfall ($r_1 = -0.568$) at this site. Further, this group comprised between 0.0-71.3% in the pond and dominated over other groups of phytoplankton between November-December (59.6-71.3%) during the first year.

In the peat bog (Site 2), Cyanophyceae density varied more widely i.e., between 2-335 n/l (49 ± 77 n/l) and depicted a distinct peak in August during the first year. Relatively high abundance of the blue green algae during the monsoon was also indicated by its positive correlation with rainfall ($r_2 = 0.468$). This group comprised between 3.0-53.2% of phytoplankton in this site and exerted their dominance only during August (53.2%) of first year. On the other hand, in the paddy-field, it registered highest mean density and varied most widely among the three sites i.e., between 0-500 n/l (58 ± 131 n/l). Relatively narrow range and low mean was registered during the first year i.e., between 0-85 n/l (16 ± 23 n/l). Higher abundance during the following year was due to significant contribution by *Nostoc* sp. bloom (200-400 n/l) during the post-paddy season (November-January). Higher abundance of this group in winter is affirmed by a significant inverse correlation with water temperature ($r_3 = -0.703$). Autumn and winter maxima of blue green algae at this site also concurred with Horne and Goldman (1994). This group comprised between 0.0-81.6% of phytoplankton and dominated during April (73.3%) in first year and November (63.6%) and December (81.6%) in second year in the paddy-field. The overall recorded mean density as well as its percentage composition at all sites is higher than the reports of Singh *et al.* (1982), Akpan (1995), Sharma (1995) and Sharma and Lyngdoh (2003)

Of the recorded blue-green algae, *Oscillatoria* sp. was predominant in the pond; its density ranged between 0-180 n/l and maximum abundance was noticed during autumn to early winter (October-January). In the peat bog, *Lyngbya* sp. (0-252 n/l) occurred in significant density during the monsoon while *Oscillatoria* sp. (0-75 n/l) was seen in greater abundance during pre- and post-monsoon period. On the other hand, in the paddy-field, *Oscillatoria* sp. (0-20 n/l) and *Phormidium* sp. (0-65 n/l) were main contributors to the group's density during the first year and it was *Nostoc* sp. (0-500 n/l) during the second. The later depicted positive correlation with nitrate ($r_3 = 0.897$) and thereby also indicated important role of this nitrogen-fixing filamentous alga in this ecosystem. Further, Cyanophyceae indicated several significant relations with abiotic factors in the pond (Site 1) including positive correlations with pH ($r_1 = 0.554$) and dissolved oxygen ($r_1 = 0.714$) and inverse relationship with specific conductivity ($r_1 = -0.519$) and sulphate ($r_1 = -0.492$). On the other hand, in the peat bog, diatoms depicted inverse relationship with specific conductivity ($r_2 = -0.546$), transparency ($r_2 = -0.564$) and total hardness ($r_2 = -0.451$).

Qualitatively minor role of Euglenophyceae, Chrysophyceae and Dinophyceae noticed presently concurred with earlier reports of Singh *et al.*, (1982), Sharma (1995), Jyrwa, (1996), Sarwar (1999), Lyngdoh (2002) and Sharma and Lyngskor (2003). Among these, Euglenophyceae was poorly represented at all sites and ranged between 0-4 n/l (1 ± 1 n/l), 0-9 n/l (1 ± 1 n/l) and 0-15 n/l (3 ± 5 n/l) respectively. *Euglena* sp. was recorded in all three water bodies (Sites 1-3) and ranged between 0-4 n/l, 0-6 in/l and 0-15 n/l respectively. Similarly, *E. acus* at Site 2 (0-4 n/l) and at Site 3 (0-15 n/l) occurred occasionally. Further, this group depicted direct significant correlations with dissolved oxygen ($r_2 = 0.675$) but inverse with sodium ($r_2 = -0.579$) in the peat bog. Further, direct correlation with other abiotic factors was indicated in the paddy-field including free CO₂ ($r_3 = 0.479$), total alkalinity ($r_3 = 0.451$), total hardness ($r_3 = 0.587$), calcium ($r_3 = 0.451$) and magnesium ($r_3 = 0.443$).

Dinophyceae, another minor group, was represented by two species viz. *Ceratium* sp. (0-5 n/l) which mainly occurred in the winters and *Glenodinium* sp. (0-6 n/l) during April-May in the peat bog. The latter was also recorded in the paddy-field in only one of the collections in November in the first year (3 n/l) This group registered direct relationship with rainfall ($r_2 = 0.672$), specific conductivity ($r_2 = 0.634$), dissolved organic matter ($r_2 = 0.473$) and phosphate ($r_2 = 0.650$). Besides, inverse relationship was also observed with

transparency ($r_2 = -0.487$), dissolved oxygen ($r_2 = -0.461$), calcium ($r_2 = -0.508$) and total dissolved solid ($r_2 = -0.512$). Similarly, Chrysophyceae, which was recorded occasionally only in paddy-field in small density was represented by *Cryptomonas* sp. It showed significant direct correlations with chloride ($r_3 = 0.447$) and sulphate ($r_3 = 0.460$) and inverse relationship with total dissolved solids ($r_3 = -0.416$).

Zooplankton: The present observations indicated high richness of zooplankton (73 species) and these belonged to seven groups namely Rotifera (38 species) > Cladocera (19 species) > Rhizopoda (9 species) > Copepoda (4 species) > Ostracoda = Nematoda =Gastrotricha (1 species each). This stated order of qualitative dominance is also concurrent with several reports from the region including Kaul *et al.*, (1978), Zutshi *et al.*, (1980), Pandit and Kaul (1982), Yousuf and Quadri (1985), Sharma (1995), Jyrwa (1996) and Lyngdoh (2002). Further, highest zooplankton species richness was registered in the paddy-field (54 species), followed by pond (50 species) and the least in the peat bog (49 species).

ANOVA exhibited significant variations in zooplankton richness between the sites ($F_{2,46} = 6.886$, $P < 0.01$). Their monthly species richness at three sites varied between 10-28 species (17 ± 4 species) in the pond (Site 1), 12-29 species (20 ± 5 species) in the peat bog (Site 2) and 13-27 species (21 ± 4 species) in the paddy-field (site 3). Maximum richness was registered in June in first year in the pond (25 species), in July of second year in the peat bog (29 species) as well as in the paddy-field (27 species), thereby, indicating greater richness in general during warmer months at all sites. However, in the pond, in addition to higher richness during early summer, secondary maxima was also recorded in December (19 species) during first year, thereby depicting a bimodal pattern of variation. On the other hand, peat bog depicted unimodal pattern of variations and registered low richness during the post monsoon months. The paddy-field, in turn, depicted a trimodal pattern of monthly variations with several small maxima i.e., in March and April (25 species each) and August (26 species) during the first year and in February (25 species), April (24 species) and October (22 species) during the second year. Overall qualitative diversity of zooplankton in present study is higher than the reports from some water bodies of Meghalaya (Sharma, 1995; Jyrwa, 1996 and Sharma and Lyngdoh, 2004) and also higher than in eight ponds in Jammu (Chowdhary *et al.*, 1988). On the other hand, the recorded richness is significantly

lower than the report by Pandit (1999) from some wetlands of Kashmir, while the values are identical to some other reports from the above state including in Mansbal Lake (Yousuf & Quadri, 1985) and in Anchar Lake (Balkhi *et al.*, 1987).

Zooplankton communities registered 57% similarity between Site 1 (pond) and Site 2 (peat bog), thereby, indicating greater heterogeneity. This was followed by 66% similarity between Site 2 and Site 3 (paddy-field) and 69% similarity between Sites 1 and 3. On the other hand, month-wise percentage similarities ranged widely between 20-90% at Site 1 and 25.8-85.7% at Site 2 indicating wide variations in their community structure and with relatively narrow range at Site 3 i.e., between 37.5-90.2%. The recorded ranges at Sites 1 and 2 are identical to the earlier reports by Sharma (1995), Sharma and Hussain (2001) and Sharma and Lynsgkor (2003) but are lower in the paddy-field than the cited reports. Further, the pond (Site 1) depicted greater heterogeneity as it showed only 52% of total instances of community similarities > 50% between different months. On the other hand, 73% and 94% instances showed > 50% community similarities in the peat bog (Site 2) and the paddy-field (Site 3) respectively, thereby, indicating greater homogeneity in zooplankton community in these two ecosystems. Highest community similarity was noted between February and March 2001 and minimum between that of August 2000 and June 2001 at Site 1. At Site 2, maximum percentage similarity was recorded between June and August 2001 and minima between July 2000 and February 2001. Similarly, maximum community similarity of zooplankton at Site 3 was recorded between August and September 2000 and minima was noted between August 2000 and May 2001.

ANOVA depicted significant variations of zooplankton abundance between three sampled sites ($F_{2, 46} = 5.247$, $P < 0.01$). Quantitative abundance of zooplankton varied within a wide range in the pond (Site 1) i.e., between 33-1071 n/l (180 ± 243) and depicted a unimodal pattern with distinct peak in first year during spring to early summer (April). This fact was attributed to bloom of the copepods during the above mentioned period. However, comparatively lower abundance (127 ± 98 n/l) was seen during the second year and therefore depicted relatively low maxima (282 n/l), coinciding with the preceding year (March). The recorded pattern of temporal variation concurred with the reports of Zutshi and Vass (1982) and Akpan (1995). On the other hand, zooplankton density varied with relatively narrow ranges i.e., between 34-123 n/l (66 ± 20 n/l) and 32-140 n/l (68 ± 27 n/l) at Site 2 (peat bog) and Site 3 (paddy-field) respectively. In addition, Site 2 (peat bog)

generally registered low and consistent population density during the first year of study except a marginally higher density (75 ± 3 n/l) during early summer (March-June). This pre-monsoon maxima was more distinct during the succeeding year and exhibited a peak during March (123 n/l). On the other hand, in the paddy-field (Site 3), zooplankton abundance varied with wider range and higher mean during the second year of study and depicted a broadly bimodal pattern. The primary maxima was registered in August (95 n/l) in first year and peak in July (140 n/l) in the second year coinciding with the active growth of the paddy. Secondary maxima were seen in the pre-paddy period in April during both the years of study (73 n/l and 139 n/l respectively). Besides, the density constantly fluctuated in this ecosystem, particularly during paddy season, thereby indicating the impact of human interventions. In addition, the minima registered in May (33 n/l) coincided with the beginning of the paddy season which could be attributed to adverse conditions created by increased turbidity after ploughing. The recorded densities and their mean values at all three sites were higher than the reports of Sharma (1995) and Jyrwa (1996) but lower than the reports of Akpan (1995). However, the values at Sites 2 and 3 are substantially lower than the reports of Singh (2000). Further, direct relationship of zooplankton abundance was indicated with calcium ($r_1 = 0.452$), sulphate ($r_1 = 0.461$), phosphate ($r_1 = 0.516$) and total dissolved solids ($r_1 = 0.517$) at Site 1; with total hardness at Sites 1 and 2 ($r_1 = 0.510$, $r_2 = 0.531$) and chloride ($r_3 = 0.429$) and silicate ($r_3 = 0.515$) at Site 3. On the other hand it indicated inverse relationship only with pH at Site 1 ($r_1 = -0.538$).

Quantitative contribution by various groups of zooplankton varied considerably at three sites. Site 1 (pond) indicated Copepoda (134 ± 227 n/l) > Cladocera (27 ± 22 n/l) > Rotifera (11 ± 4 n/l) > Rhizopoda (7 ± 4 n/l) > Ostracoda = Nematoda = Gastrotricha (1 ± 1 n/l) and hence indicated a distinctly significant role of the copepods. At Site 2 (peat bog), they were comprised of Cladocera (20 ± 15 n/l) > Rotifera (15 ± 6 n/l) > Copepoda (14 ± 7 n/l) = Rhizopoda (14 ± 4 n/l) > Ostracoda = Nematoda (2 ± 1 n/l each) depicting almost equal role of the first four major groups of zooplankton in this water body. On the other hand, in the paddy-field, they exhibited Rotifera (21 ± 13 n/l) > Cladocera (18 ± 8 n/l) > Copepoda (13 ± 5 n/l) = Rhizopoda (13 ± 4 n/l) > Ostracoda = Nematoda = Gastrotricha (1 ± 1 n/l each). Quantitatively significant role of three major groups of zooplankton at all three sites is consistent with the reports of Sharma (1995), Das *et al.* (1996), Jyrwa (1996), Lyngdoh (1998) and Lakiang (1998). The numerical sequence of dominance order of

Rotifera > Cladocera > Copepoda > Rhizopoda in the paddy-field (Site 3) is also in conformity with the reports by Vyas *et al.* (1988), Sharma (1995), Jyrwa (1996), Lyngdoh (1998), while this is contrary to report of Pandit (1999). However, the later report, in turn, is identical to the findings at Site 1 (pond) and Site 2 (peat bog) of the present study. Similarly, the quantitative dominance by copepods in the pond was concurrent with the reports of Pandit and Kaul (1982) and Vyas *et al.* (1988). However in the presently studied biotopes, the role of Rhizopoda in total zooplankton density was also important in addition to the three main groups.

Further in the pond, copepods continued to be dominant group from February-August while Cladocera and Rhizopoda shared a percentage composition of 44.9-66.7% and were dominant between June-January. At Site 2 (peat bog), the percentage composition of the four important groups including Rhizopoda was almost identical. Copepoda exhibited its numerical dominance between February-March in first year only (41.1-41.8%) but Cladocera was dominant during April-May (35.1-34.6%). In second year, later dominated between January-July (30.4-65%) but it was Rhizopoda during July-December (31.1-45.2%) in first year and during August-September (26.2-34.4%) in second year. Rotifera was a sub-dominant group during September (36.6%) in first year and during November-January (27.5-43.9%) in the second year. On the other hand, in the paddy-field (Site 3), Rotifera dominated for a longer duration between April-October in first year (31.3-56.2%) but fluctuated inconsistently dominating other groups only during February (33.8%), June (43.2%) and July (41.4%) of second year. Similarly, Cladocera comprised quantitatively dominant group between February-March (40.7-35.1%) during the first year and between December-January (30-33.3%) as well as from August-January (29.7-38%) in the second year of the study. Copepoda was dominant only between April-May (39.6-40.5%) during the second year.

Species diversity of zooplankton *vide* Shannon's index (H') showed a relatively wider range and higher mean at Site 1 (pond) and ranged between 0.930-3.232 (2.306 ± 0.815). At Site 2 (peat bog) and Site 3 (paddy-field) it ranged between 1.871-3.24 (2.745 ± 0.293) and 2.397-3.676 (2.904 ± 0.249) respectively registering the order of species diversity at three sites as, Site 3 (paddy-field) > Site 2 (peat bog) > Site 1 (pond). On the other hand, diversity *vide* Menhinicks's registered a little lower values; these ranged between 0.458-2.858 (1.843 ± 0.788), 1.172-3.255 (2.474 ± 0.430) and 1.768-3.467 (2.647

± 0.510) at three sites respectively and affirmed the above stated decreasing order in the three ecosystems. The recorded zooplankton diversity was higher than the reports of Sharma (1995), Wanswett (2001) and Sharma and Lyngdoh (2004) but marginally lower than report of Singh *et al.* (1982). Broadly, the diversity values were identical during both the years at all sites and depicted unimodal pattern of monthly variations at Site 1 (pond) and multimodal trends at Site 2 (peat bog) and Site 3 (paddy-field). Further, relatively high zooplankton diversity was observed from summer to early winter (June-December) in the pond and distinctly low between February-May. In contrast, Sites 2 and 3 registered relatively high diversity during early summer (April-July). In addition, the peat bog generally depicted consistently high zooplankton diversity during the study period except in March (minima) of second year. Based on these moderately high species diversity, the sampled water bodies could be categorised as 'mesotrophic' following Datta (2001). Besides, the diversity indicated positive correlation with evenness ($r_1 = 0.970$, $r_2 = 0.689$, $r_3 = 0.644$) and inverse relationship with species dominance ($r_1 = -0.972$, $r_2 = -0.846$, $r_3 = -0.595$) at all sites as well as with zooplankton abundance at Site 1 ($r_1 = -0.765$). Inverse relationship with dominance concurred with the report of Sharma and Lyngdoh (2004). Further, it also registered significant positive relationship with species richness ($r_2 = 0.876$, $r_3 = 0.745$) at Sites 2 and 3.

Zooplankton dominance (*vide* Berger-Parker's index) ranged between 0.184-0.815 (0.450 ± 0.227), 0.108-0.488 (0.185 ± 0.084) and 0.077-0.329 (0.140 ± 0.056) at Site 1-3 respectively. Similarly it ranged between 0.102-0.779 (0.360 ± 0.238), 0.037-0.267 (0.074 ± 0.046) and 0.030-0.122 (0.054 ± 0.022) respectively *vide* Simpson's index during the study period and the two corresponded to each other in all months. Mean values indicated moderate dominance at Site 1 (pond) and low dominance at other two sites with minimum in the paddy-field. In addition, monthly variations indicated more fluctuations in the second year at Site 2 (peat bog) and Site 3 (paddy-field) and were almost identical during both years at Site 1 (pond). Further, the pond depicted a trimodal pattern of temporal variations with maxima during the pre-monsoon months and registered peak in May during the first year. The period of higher zooplankton dominance broadly corresponded with the copepod bloom during both annual cycles of study period. On the other hand, in the peat bog (Site 2) as well as in the paddy-field (Site 3), low dominance was recorded throughout the study period with lesser fluctuations in their temporal variations. Relatively lower dominance was

recorded during the monsoon in the peat bog (0.056-0.089) and during paddy seasons in the paddy-field (0.03-0.076). Further, the recorded values were significantly higher at Site 1 but marginally lower at Sites 2 and 3 than the reports of Sharma and Lyngdoh (2004). The dominance also depicted inverse correlations with evenness ($r_1 = -0.951$, $r_2 = -0.892$, $r_3 = -0.658$) at all sites as well as with species richness ($r_2 = -0.539$) only at Site 2 and with zooplankton abundance ($r_1 = 0.718$) at Site 1. The above relationships also concurred with the reports of Sharma and Lyngdoh (*loc.cit.*).

Evenness (E_1) computed at Sites 1-3 indicated high equitability of zooplankton at all sites and ranged between 0.343-1.134 (0.823 ± 0.280), 0.729-0.967 (0.925 ± 0.049) and 0.853-1.142 (0.959 ± 0.052) respectively. The present study depicted identical annual ranges and mean values of evenness at Site 1 (pond) and Site 2 (peat bog) but exhibited marginally wider range during second year at Site 3 (paddy-field). Further a unimodal pattern of its monthly variations was depicted at Site 1 (pond) with higher richness during monsoon to mid-winter (June-January) during both the annual cycles and the trend broadly corresponded with the species diversity. However, zooplankton evenness did not depict significant monthly variations in the peat bog (Site 2) as well as paddy-field (Site 2) and was consistently high during the study period. However, paddy-field depicted marginally higher maxima in April of first year. Evenness did not depict any significant correlation with species richness or with zooplankton abundance. Further, recorded richness was identical to report of Sharma and Lyngdoh (2004) but higher than the reports of Lyngdoh (1998) and Wanswett (2001).

Among the recorded groups of zooplankton, Rotifera was qualitatively dominant in all three water bodies and exhibited Site 3 (28 species) > Site 2 (23 species) > Site 1 (22 species). It, however, registered lower monthly species richness i.e., between 2-10 species (5 ± 2 species), 3-12 species (7 ± 2 species) and 4-15 species (8 ± 3 species) at Sites 1-3 respectively depicting highest value in the paddy-field and the least in the pond. Further, ANOVA indicated significant variations in species richness of Rotifera between different sampling sites ($F_{2, 46} = 18.492$, $P < 0.01$). It fluctuated with unimodal pattern at Site 1 (pond) as well as at Site 2 (peat bog) with maxima during warmer months i.e., in June in first year (10 species) and between June-August in second year (7 species) at Site 1 and in April (12 species) and July (11 species) respectively at Site 2. On the other hand, Site 3 (paddy-field) registered a bimodal pattern of fluctuation with primary maxima recorded in August

(14 species) and July (15 species) and secondary maxima in April (12 species) and February (10 species) during the two years respectively. Further at this site, generally higher rotifer richness was observed during the period of active growth of paddy, which also concurred with the report of Jyrwa (1996). Of the recorded rotifer species in these three water bodies, *Epiphanes* sp., *Lecane aculeate*, *L. luna*, *L. lunaris*, *Lepadella ovalis*, *L. patella* and *Philodina* sp. were common in all three sites. However, *Lecane hornemanni*, *Mytilina ventralis* and *Platytias polyacanthus* were recorded only in the pond. Similarly, *Anuraeopsis* sp., *Dicranophorus* sp. and *Lecane doryssa* were restricted in the peat bog. *L. papuana*, *L. quadridentata*, *Lepadella acuminata*, *Platytias patulus* and *Trichocerca rattus* were recorded only in paddy-field. Further lecanids with 11 species at all three sites comprised the single large family representing almost 29% of their total rotifer fauna. This finding was also concurrent with several earlier reports (Sharma, 1995; Jyrwa, 1996; Sharma and Sharma, 1999; Sharma and Lyngdoh, 2004).

Analysis of qualitative planktonic samples from other standing water bodies, mostly from eastern Bhutan, registered 60 species of rotifers that belonged to 28 genera and in turn represented 17 families. It exhibited Lacanidae (18 species) > Brachionidae (12 species) > Colurellidae (6 species) > Trichocercidae (5 species) > Notommatidae (3 species) > Trichotridae = Synchaetidae = Testudinellidae = Philodinidae (2 species each) > Epiphanidae = Mytilinidae = Euchlanidae = Asplanchnidae = Gastropodidae = Dicranophoridae = Conochilidae = Filinidae (1 species each). Recorded diversity of rotifers is slightly higher than that of Nepal (Daems and Dumont, 1974) and depicted 63% of community similarity with the later report. On the other hand, the present diversity is substantially lower than the reports of Sharma and Sharma (1999a) from the state of Meghalaya, India (124 taxa), which in turn, showed 59.8% of similarity with the present records. Further, majority (70%) of recorded taxa were cosmopolitan in distribution. Eleven species comprised of sub-tropical elements viz., *Brachionus bidentatus*, *B. quadridentatus*, *Keratella tropica*, *Macrochetus sericus*, *Lecane aculeate*, *L. crepida*, *L. curvicornis*, *L. hornemanni*, *L. leontina*, *L. papuana*, and *L. ploenensis*. The later along with *Lecane scutata*, an arctic temperate taxa, *L. doryssa*, *Keratella cochlearis* and *Squatina mutica* represented acidophilic elements (Sharma and Sharma, 1999) in the generally acidic waters of the studied biotopes.

The rotifer composition indicated that three families of the order Ploimida i.e., Lecanidae, Brachionidae and Colourellidae, in the stated order, comprised the dominant fraction (60%). This fact also concurred with the findings of Sharma and Sharma (1999) but differed slightly from the results of Daems and Dumont (1974), who in turn, have reported Lecanidae > Colurellidae > Trichocercidae > Brachionidae. Further, in the present investigation, Brachionidae comprised of six species of genus *Brachionus*, one of the ancient genera of the monogonont rotifers and believed to be of Gondwanian origin (Dumont, 1983). Even though they are known to occur mostly in the alkaline waters (Koste, 1978), they were recorded in slightly acidic to alkaline waters (pH 6.48-8.29) during the present study. This finding also corroborates with the observations by Sharma and Sharma (1999) under similar pH conditions. However, *B. calyciflorus* exhibited its typical alkalophilic affinity and was recorded only in the alkaline sewage stabilization pond (pH 8.29), and a fishpond (pH 7.45). General alkalophilic affinity of this genus (Sharma, 1983) is, however, affirmed by its absence in the acidic peat bog. Of the brachionids, genus *Keratella*, known to exhibit widest latitudinal range (Pejler, 1977), was represented by three species during the present study. *Keratella cochlearis*, a common planktonic species of the temperate region but supposedly absent from the tropics (Sládeček, 1983), was found in only a single collection from the foothills. On the other hand, *K. tropica*, a dominant rotifer of peninsular India (Sharma and Sharma, 1999) was recorded from three sites representing wide variations in alleviations (250-4175 m ASL). In addition, a *Keratella* sp. of inconclusive taxonomic nomenclature was recorded in four ponds (2570-3150 m ASL) in east Bhutan indicating its cold water affinity. It is characterised by presence of anterior spines typical of a *Keratella* but absence of distinct ornamentations on its dorsal plate as well as very short or complete absence of posterior spines, the latter characteristics, in turn, indicating its *Brachionus* affinity. Two other genera of the family Brachionidae, *Platyias* and *Anuraeopsis* were represented by two and one species each respectively. Of the former, the cosmopolitan *Platyias quadricornis* showed a rare occurrence during the present study. In addition, a species of biogeographical importance included *Platyias polyacanthus*, a rare species in the sub-continent and was recorded from relatively wider range of alleviations (300-2600m ASL) at three locations during the present investigation. Similarly, the cosmopolitan and warm stenothermal *Anuraeopsis fissa* indicated wide distribution.

Lecanidae comprised the largest family of rotifers and was represented by 18 species (30% of recorded rotifer taxa), of which ten belonged to *Lecane* (*Lecane*) and eight to *Lecane* (*Monostyla*). They were most widely distributed but were absent in the alkaline waters of sewage stabilisation pond (Site 5) and two temperate water bodies (glacial lakes). The absence of this group as well as other species in the latter ecosystems was mainly owing to paucity of material for the present study. Further, qualitative abundance of the lecanids in the studied biotopes in Bhutan confirms to the characteristics of rotifer communities in the oriental region (Sudzuki, 1989). Various taxa of lecanids recorded could be assigned to following distribution *vide* Segers (1996):

Arctic temperate taxa: *Lecane scutata*;

Tropicopolitan taxa: *Lecane aculeata*, *L. crepida*, *L. curvicornis*, *L. doryssa*, *L. hornemanni*, *L. leontina* and *L. papuana*;

Cosmopolitan taxa: *Lecane bulla*, *L. clostercerca*, *L. hamata*, *L. inermis*, *L. luna*, *L. lunaris*, *L. quadridentata*, *L. unguolata* and *L. pyriformis*.

Besides, *Lecane aculeata* and *L. quadridentata* represented warm-stenothermal lecanids, whereas *L. inermis* was recorded from a fishpond in the foothills as well as from a pond at 1930 m ASL, representing wide range in water temperature (12.1-29.0° C), thereby affirming its eurythermal characteristic (Kutikova, 1970). Further, six members of family Colurellidae were recorded during the present study of which *Lepadella acuminata* and *Squatinella mutica* showed rare occurrence in the examined material. The rarity of the latter species also concurred with the reports of Sharma and Sharma (1999). On the other hand, *Lepadella patella* as well as *L. ovalis* showed wide distribution.

Family Trichocercidae comprised another important group of phylum Rotifera with five species recorded during this study. Of the recorded members of this family, *Trichocerca cylindrica* is biogeographically important element as it was earlier reported from Palaearctic and Nearctic region and Sri Lanka as well as from Meghalaya (Sharma, 1999). While the cosmopolitan *Trichocerca pusilla* was also widely distributed during this study, *T. similis* was recorded only from an ephemeral pond at the foothills. Three species of recorded notommatid rotifers (Family Notommatidae) included *Cephalodella* sp., *Scaridium longicaudum* and *Monommata longiseta*. The later is an important species as it is reported from only West Bengal and Meghalaya in this region (Sharma, 1999). Of the other families of Ploimida, Syanchaetidae comprised of two species, while Asplanchnidae,

Gastropodidae, Euchlanidae and Dicranophoridae were represented by one species each. Of the latter, *Dicranophorus* sp. an acidophilus taxa (Myers, 1934) was also recorded only in the acidic peat bog (Site 2) during the present study. *Epiphanes* sp. (Family: Epiphanidae) comprised a new generic addition to the eastern Himalayan fauna.

Only three families of Order Gnesiotrocha are represented in this study, of which *Conochilus* sp. (Family: Conochilidae), the only colonial rotifer examined, showed relatively wide distribution. Family Filinidae was represented by cosmopolitan *Filinia longiseta* and was mainly collected from eutrophic waters during the present study. Similarly, *Testudinella patina* was the only recorded member of family Testudinellidae. The digonont rotifers of the order Bdelloidea was represented by two members of the family Philodinidae, of which *Rotatoria* sp. exhibited a rare occurrence, while *Philodina* sp. was more widely distributed.

Further, three selected ecosystems (Sites 1-3) in east Bhutan (1640-1930 m ASL) represented 62% of total rotifers documented, as adequate samples were available from these regularly monitored biotopes. On the other hand, relatively higher species richness was seen at lower altitude (foothills) as 53% of the total rotifers were recorded in single sampling attempts each together at Site 11 (23 species) and Site 9 (18 species), which are an ephemeral pond and a fishpond respectively. Further, other sites with relatively higher richness include Site 15 (an ephemeral pond at 2600 m ASL) and Site 8 (a pond at 1600 m ASL) both of which registered 15 species each. Percentage similarities computed between the above four sites with relatively higher richness as well as the regularly sampled biotopes (Site 1-3) ranged between 21.7-66.7% ($41.0 \pm 11.9\%$) and indicated heterogeneity of rotifer communities in these diverse ecosystems. While maximum similarity was observed between Site 2 (peat bog) and Site 3 (paddy-field), minimum was recorded between Sites 8 and 11, a relatively high altitude pond and a foothill pond respectively. Further, low rotifer diversity in many of the sampled water bodies is apparently owing to inadequate frequency of samplings for present investigation. In addition, paucity of large and permanent standing water bodies owing to steep terrain and poor accessibility caused insufficient representation of this intricately mountainous country.

Regarding the monthly quantitative abundance of rotifers in three regularly monitored ecosystems, they varied significantly ($F_{2, 46} = 10.438$, $P < 0.01$) between sites and ranged between 6-21 n/l (11 ± 4 n/l) at Site 1 (pond) and 5-30 n/l (15 ± 6 n/l) in the

peat bog (Site 2). On the other hand the rotifers registered wider range and comparatively higher mean of 9-58 n/l (21 ± 13 n/l) in the paddy-field, thereby, indicating its most important quantitative role in the later ecosystem. This fact was also affirmed by a significant positive correlation with zooplankton ($r_3 = 0.657$). Significant role of the planktonic and semi-planktonic rotifers in the aquatic food chain in this ecosystem concurred with the earlier reports of Nasar (1977), Yadava *et al.* (1987), Ravichandran and Ramanibai (1988), Sharma (1995), Alfred and Thapa (1995), Patil and Karikal (2001) and Prakash (2001). In addition, monthly density of rotifers varied with a unimodal pattern with higher abundance during the period of active growth of the paddy. Distinct maxima were recorded in August (54 n/l) and July (58 n/l) of two annual cycles respectively. Prevalence of higher rotifer abundance during warmer monsoon months is also indicated by its direct relationship with water temperature ($r_3 = 0.454$) and rainfall ($r_3 = 0.504$). Further, lower abundance (10 n/l) during both the years corresponded with the beginning of the paddy season (May), which could be owing to the impact of adverse conditions caused by ploughing and thereby, increased turbidity (Fernando, 1993).

On the other hand, the rotifers were quantitatively sub-dominant group at Site 2 (peat bog) and third in the order at Site 1 (pond) and exhibited bimodal patterns of their monthly variations at both these sites. Further, in the pond, the primary maxima was seen in June (21 n/l) and secondary in December (15 n/l) during the first year while they corresponded in July (19 n/l) and March (14 n/l) respectively during the succeeding year, indicating higher abundance during pre-monsoon to early monsoon. In the peat bog, generally higher abundance was recorded during summer to early winter (June-December) during both the annual cycles and depicted maxima in June (22 species) and November (16 n/l) during the first year. However, higher abundance was recorded during the second year than in the preceding year and registered distinct peak in July (30 n/l) and almost identical secondary maxima (29 species) in December.

The percentage composition of rotifers ranged between 0.8-30.6% ($14.6 \pm 9.4\%$), 6.5-43.9% ($23.4 \pm 7.6\%$) and 12.7-56.8% ($30.9 \pm 11.2\%$) at Sites 1-3 respectively, thereby, indicating their lesser impact at Site 1 (pond) and relatively more at the other two sites. In the peat bog (Site 2), it dominated over the other groups only in June (31%) and September (36.6%) in first year and between November-January (27.5-43.9%) of the second year of study. On the other hand, in the paddy-field, it was numerically dominant for a longer

period in first year i.e., between April-November (31.3-56.8%) and in February (33.8%) as well as during June-July (41.4-43.2%) in the second year.

Among the reported species of this phylum, *Euchlanis dilatata* was quantitatively important species at all sites and ranged between 0-7 n/l, 0-4 n/l and 0-11 n/l at Sites 1-3 respectively registering higher density during warmer months. Similarly *Testudinella patina* at Site 1 (0-7 n/l) was seen in its peak density in January (second year) and was generally more abundant during pre-monsoon months. At Site 2 (peat bog), *Cohurella obtusa* (0-6 n/l) and *Philodina* sp. (0-6 n/l) showed their maxima in September in first year and October and July respectively in the second year of the study period, depicting their higher abundance during the monsoon. Further at this site, *Anuraeopsis fissa* was recorded in significant density (4-17 n/l) only during November-January in the second year of study. Similarly, *Brachionus quadridentatus* at Site 3 (paddy-field) depicted high abundance only during two months of study from June-July (5-11 n/l) during the second year. Further, *Epiphanes* sp. (0-13 n/l) depicted its peak density during the active growth of paddy (July) in second year and was not recorded in post-paddy season (November-January). The abundance of *Lecane bulla* (0-9) at this site broadly followed bimodal pattern of fluctuation with peak during August 2000 in first year and the primary maxima (8 n/l) during February in second year. *Lepadella patella* (0-6 n/l) showed most common occurrence and was recorded in almost all the months.

Rotifera indicated direct significant correlations with specific conductivity ($r_1 = 0.514$), calcium ($r_1 = 0.513$) and nitrate ($r_1 = 0.643$) at Site 1 (pond) and with alkalinity ($r_2 = 0.438$) at Site 2 (peat bog). On the other hand, inverse relationship is noticed with transparency ($r_2 = -0.407$), sulphate ($r_2 = -0.503$) and potassium ($r_2 = -0.439$) at Site 2 and with phosphate ($r_3 = -0.477$) at Site 3 (paddy-field). Further, the rotifers shared significant relationships with other biotic components including Gastrotricha ($r_1 = 0.431$), Nematoda ($r_2 = 0.636$) and Rhizopoda ($r_3 = 0.533$) at Sites 1-3 respectively.

Cladocera, second qualitatively important group at all sites, registered 16 species at Site 1 followed by 13 species each at Site 2 and Site 3 and comprised 19 species in all. ANOVA indicated significant variations between months ($F_{23, 46} = 3.34$, $P < 0.01$) but insignificant between sites. Species richness of the group at three sites ranged between 2-12 species (6 ± 3 species), 3-9 species (5 ± 2 species) and 3-8 species (6 ± 1 species) respectively. The former richness is broadly identical to the reports from Meghalaya

(Alfred and Thapa, 1995; Sharma, 1995 and Das *et al.*, 1996) but is lower than reports from Nepal (Swar and Fernando, 1979). Further, percentage similarities between presently recorded richness with that of Nepal and with cladoceran fauna of Meghalaya state (Sharma and Sharma, 1999) were 61.8% and 52% respectively, thereby, indicating sizeable variations between their community structure. On the other hand, among three studied ecosystems, least percentage similarity (48%) was recorded between pond and the peat bog exhibiting significant variations in their cladoceran community structure. However, greater similarity was noticed between pond and paddy-field (75%) as well as between peat bog and the paddy-field (69%).

Further, in the pond as well as in the peat bog, Cladocera generally recorded higher species richness prior to monsoon with maxima in June (11 species) during first year at Site 1 and during April (9 species) at Site 2. Similarly, the peak was depicted in May (12 species) at Site 1 during the second year. On the other hand, in the paddy-field (Site 3), a broadly bimodal pattern was seen with maxima registered in pre-paddy seasons and the paddy seasons during both annual cycles. Among the common members of this group, *Alona costata* depicted regular occurrence at all sites. *Macrothrix laticornis* showed rare occurrence during rainy season only i.e., between July-August during second year at Site 1 (pond) and between June-July and July-August in the two annual cycles respectively at Site 2 (peat bog). However at Site 3 (paddy-field), it was seen for longer duration (May-November) during both the years. Similarly, *Moina micrura* was recorded during the warmer months (April-August) only in first year at Site 1, during spring to early summer (February-May) at Site 2 but only in January of first year at Site 3. *Pleuroxus similis* was recorded at all sites but occurred more regularly at Site 3 (paddy-field). While *Alona affinis* was recorded only in the pond occasionally, *Diphanosoma excisa* was observed only in April in first year and January-February in second year only at Site 2 (peat bog). Further, only the latter site registered regular occurrence of *Simocephalus serrulatus* and *Daphniopsis* sp., which in turn, was recorded during early spring to early summer i.e., between March-June in first year and February-May in second year.

Monthly abundance of Cladocera varied with relatively wider range at Site 1 (pond) and Site 2 (peat bog) i.e., between 7-110 n/l (27 ± 22 n/l) and 6-80 n/l (20 ± 15 n/l) respectively and with narrow range between 9-44 n/l (18 ± 8 n/l) at Site 3 (paddy-field). ANOVA indicated significant variations in their abundance between months ($F_{23, 46} =$

2.236, $P < 0.05$) but insignificant variations between sites. In the pond (Site 1), monthly abundance of cladocerans followed a unimodal pattern of variations during first year and a broadly bimodal pattern during second year with its peak density in April coinciding with that of zooplankton abundance, thereby indicating its significant role at this site. This is further confirmed by its highly significant correlation between them ($r_1 = 0.998$). This subdominant group of zooplankton in the pond co-occurred with copepods following broadly similar trend of density variations during the study period. This fact was also supported by a significant positive correlation between the two groups ($r_1 = 0.845$). However at Site 2 (peat bog), it depicted unimodal pattern of monthly variations with low cladoceran abundance during monsoon and showed its peak density (44 n/l) in April of second year coinciding with copepod maxima, which in turn, showed significant positive correlation ($r_2 = 0.712$). Further, a significant variation in its abundance between two years was indicated by ANOVA ($F_{2, 11} = 4.972$, $P < 0.05$). It ranged less widely with low mean that is between 6-27 n/l (15 ± 7 n/l) during first year against a wider range and higher mean i.e., between 9-80 n/l (25 ± 19 n/l) in the succeeding year. Higher abundance was recorded during the spring with peak in March (80 n/l) during the second year and relatively lower maxima in May (27 n/l) during the preceding year. On the other hand, at Site 3 (paddy-field), bimodal pattern of their monthly variations was recorded with higher abundance of cladocerans observed during pre-paddy period and low density during the paddy season (9-12 n/l) in first year. However, it also depicted small maxima during the active period of paddy growth in July (32 n/l) of second annual cycle. Occurrence of single maxima of cladocerans at Site 1(pond) during first year and in the peat bog during both the annual cycles of study period concurred with the report of Yousuf and Quadri (1985), while bimodal patterns during second year at Site 1 and in both annual cycles at Site 3 concurred with the report by Balkhi *et al.* (1987). Further, the reported density of Cladocera at all sites above is marginally higher than the report by Lyngdoh (2002) but identical to the report by Pandit (1999).

Monthly percentage composition of cladocerans ranged between 4.4-44.9% ($23.5 \pm 11.3\%$) in the pond, 12.9-65.0 % ($29.1 \pm 13.5\%$) in the peat bog and 9.5-40.7% ($28.2 \pm 8.3\%$) in the paddy-field. In the pond, they were numerically dominant only during January in first year (38%), while they exerted dominance for a longer duration in second year i.e., between June-August (37-44.9%) and October-December (28.2-37.8%). In the peat bog, it

dominated over other groups during early summer i.e., between April-June (26.8-35.1%) in first year and between January-July (30.4-65%) in second year. On the other hand, in the paddy-field, the percentage composition of Cladocera was higher than the other groups in 15 out of 24 months thereby depicting its overall dominance at this site. It exerted its dominance mostly during the pre-paddy and post-paddy seasons and hence it was a sub-dominant group between July-October in first year and May-June in the second year.

Among the recorded members of this group, *Chydorus sphaericus* was a regular species at all sites and its density ranged between 0-16 n/l, 0-7 n/l and 0-17 n/l at Sites 1-3 respectively. Monthly variations in density of this species depicted a broadly unimodal pattern at all sites with peak during warmer months i.e., during June in the pond and during July in the peat bog as well as in the paddy-field. In addition, *Ceriodaphnia reticulata* (0-99 n/l) exhibited its bloom during February-April (12-99 n/l) during the first year in the pond. Along with this species, *Ceriodaphnia cornuta* occurred in significant density (0-32 n/l) from January-May, mainly during second year. At Site 2 (peat bog), zooplankton maxima in March 2001 was mainly due to *Daphniopsis* sp. (60 n/l), which exhibited a seasonal occurrence in early summer. The other quantitatively important species at this site were *Simocephalus serrulatus* (0-12 n/l) and *Alona guttata* (0-12 n/l), whose peak density also coincided with *Daphniopsis* sp. bloom. At Site 3 (paddy-field), on the other hand, *Pleuroxus similis* (0-11 n/l) and *Alona costata* (1-9 n/l) depicted bimodal pattern of their monthly density variations and occurred in higher abundance during pre- and post-paddy seasons. Further, direct correlation of cladocerans existed with total alkalinity ($r_1 = 0.497$), calcium ($r_1 = 0.434$) and phosphate ($r_1 = 0.424$) at Site 1 (pond) and with sodium ($r_2 = 0.466$), magnesium ($r_2 = 0.556$) and phosphate ($r_2 = 0.670$) at Site 2 (peat bog). Similarly, at Site 3 (paddy-field) it indicated direct relationship with dissolved oxygen ($r_3 = 0.461$), magnesium ($r_3 = 0.481$) and silicate ($r_3 = 0.447$). On the other hand, inverse relationship is seen with pH ($r_1 = -0.520$) at Site 1 and total dissolved solids ($r_3 = -0.439$) at Site 3.

Rhizopoda, third qualitatively important group at all sites consisted of 7 species at Site 1 (pond) and 8 species each at Site 2 (peat bog) and Site 3 (paddy-field) comprising a total of 9 species. A significant variation in species richness was indicated by ANOVA between the sites ($F_{2, 46} = 10.308$, $P < 0.01$). It ranged between 1-6 species (3 ± 1 species) at Site 1, 2-7 species (5 ± 1 species) at Site 2 and 3-7 species (5 ± 1 species) at Site 3. The present study indicated higher overall qualitative as well as quantitative abundance of

rhizopods than the reports of Sharma (1995), Jyrwa (1996), Das *et al.*, (1996) and Lyngdoh (2002). However, it is significantly lower than reports of Pandit (1999). Among the group, *Arcella* sp. was recorded only at Site 1 and others viz. *A. discoides*, *A. megastoma*, *Centropyxis aculeata*, *C. ecornis*, *Diffflugia* sp., and *Euglypha* sp. occurred at all the studied biotopes. Further, a significant variation was seen in the abundance between sites ($F_{2, 46} = 15.033$, $P < 0.01$). Monthly abundance of rhizopods varied with a narrow range and low mean at Site 1 (pond) i.e., between 2-18 n/l (7 ± 4 n/l). On the other hand, wide ranges and higher mean values were recorded in the peat bog as well as in the paddy-field, which in turn, ranged between 4-32 n/l (14 ± 7 n/l) and 5-24 n/l (13 ± 5 n/l) respectively. Further, in the pond, it exhibited higher abundance during autumn to early winter (October-December) and was relatively low during the pre-monsoon months. The latter could be mainly owing to competition by copepods as also indicated by their inverse relationship ($r_1 = -0.410$). In the peat bog, relatively higher abundance was seen during warmer months, particularly during the monsoon, and low in the winter months. This fact is further affirmed by their direct relationship with water temperature ($r_2 = 0.579$) and rainfall ($r_2 = 0.522$). In addition quantitatively importance of this group in the peat bog is further affirmed by its positive correlation with net plankton ($r_2 = 0.590$).

On the other hand, in the paddy-field, quantitative importance of this group is indicated by its direct relationship with zooplankton ($r_3 = 0.658$). Rhizopoda exhibited greater monthly fluctuations in its density and depicted trimodal pattern in the paddy-field with peak density during the period of active growth of paddy (July-August) and generally low density was seen in early part of paddy season (May-June) coinciding with the ploughing and plantation activities.

Percentage contribution of rhizopods to zooplankton at Site 1 (pond) was relatively low which ranged between 0.28-33.3% ($12.1 \pm 11.8\%$). It was, however, a co-dominant group during September (25.7%) and December (30.6%) and dominant between October-November (30.6-40%) only during the first year. On the other hand it ranged more widely i.e., between 4.0-45.2% ($22.8 \pm 9.9\%$) at Site 2 (peat bog) and exerted its numerical dominance during monsoon and early winter i.e., between July-August (31.1-45.2%) and October-December (31.7-33.3%) in first year and between August-September (26.2-34.4%) during the second year. On the other hand, at Site 3 (paddy-field), it registered narrow

range of 8.57-30.0% ($19.9 \pm 5.5\%$) and was a co-dominant group only during December (30%) in first year and sub-dominant during August and November in first year and February and December in second year.

Rhizopoda was represented by *Diffugia* sp. at all three sites with 0-4 n/l, 1-9 n/l and 0-6 n/l respectively. In addition, *Euglypha* sp. at Site 1 (0-5 n/l), *D. lebes* at Site 2 (0-12 n/l) and *Arcella megastoma* at Site 3 (0-11 n/l) constituted quantitatively important taxa. Rhizopoda depicted positive correlations with pH ($r_1 = 0.491$) and dissolved oxygen ($r_1 = 0.479$) at Site 1 (pond). On the other hand, inverse relationships were seen with sulphate ($r_1 = -0.512$) and phosphate ($r_1 = -0.515$) at Site 1 and with transparency ($r_2 = -0.597$), specific conductivity ($r_2 = -0.695$), sodium ($r_2 = -0.537$), potassium ($r_2 = -0.651$) and sulphate ($r_2 = -0.435$) at Site 2 (peat bog). Similarly it also shared direct relationship with phytoplankton ($r_1 = 0.661$, $r_2 = 0.565$), Bacillariophyceae ($r_1 = 0.458$), Chlorophyceae ($r_2 = 0.465$) and Cyanophyceae ($r_2 = 0.478$).

Copepoda formed quantitatively most important group at Site 1 (pond) and a co-dominant group at other two sites. However, it indicated only four species in all with Site 2 (3 species) > Site 1 = Site 2 (2 species). Monthly species richness ranged between 1-2 species (1 ± 1 species), 1-3 species (2 ± 1 species) and 1-2 species (1 ± 1 species) at Sites 1-3 respectively. The number of species recorded in the present study is marginally higher than the reports of Yousuf *et al.*, (1983) and Kundangar and Zutshi (1985) in some wetlands of Kashmir as well as it is higher than the reports by Sharma (1995), Jyrwa (1996) and Lyngdoh (2002). However, it is significantly lower than the reports by Kaul *et al.* (1978), Zutshi *et al.* (1980), Subla *et al.* (1984), Yousuf and Quadri (1985) and Balkhi *et al.* (1987). Of the group, *Tropocyclops* sp. was recorded at all sites and was observed in all their monthly collections, while *Eucyclops* sp. was observed at Site 1 and Site 2 occasionally. *Diaptomus* sp. was recorded only at Site 2 and occurred in three monthly collections during early spring i.e., March 2000, February and March 2001. At Site 3, *Allodiaptomus* sp. was recorded between January-April of both the years.

Monthly abundance of Copepoda ranged widely between 6-950 n/l (134 ± 227 n/l) at Site 1 (pond) while it varied with narrow ranges and lower mean values at Site 2 (peat bog) and Site 3 (paddy-field) i.e., between 4-33 n/l (14 ± 7 n/l) and 5-55 n/l (13 ± 5 n/l) respectively. Higher abundance of copepods was registered between March-April at all sites thus also depicting its spring bloom in the pond. This is in contrast to reports of Patil

and Gouder (1985), Kaushik and Sharma (1994), Jyrwa (1996) and Lyngdoh (2002) where winter maxima is reported. Further, Copepoda density exhibited unimodal pattern of monthly variations at all sites, which, however, concurred with reports of Negi and Pant (1983), Quadri and Yousuf (1987) and Lyngskor (1997).

ANOVA indicated significant variations in abundance of copepods between the sampled sites ($F_{2, 46} = 6.865$, $P < 0.01$). At Site 1 (pond), Copepoda exhibited high abundance during spring and depicted a distinct peak in April in first year while the maxima of comparatively lower magnitude was observed in March (223 n/l) during the succeeding year. High abundance coincided with low water level during the relatively dry spring and early summer seasons, which apparently result in greater concentration of the nutrients. Positive relationship of copepod abundance with sulphate ($r_1 = 0.462$), phosphate ($r_1 = 0.519$) and total dissolved solids ($r_1 = 0.520$) also indicated towards the above fact. On the other hand, low abundance of the copepods was observed between August-December (6-16 n/l) during both the annual cycles of the study period. In addition, the density also ranged less widely and with low mean i.e., between 9-223 n/l (81 ± 93 n/l) during the second year. Most dominant quantitative role of copepods in this water body is further affirmed by its highly significant direct correlations with zooplankton ($r_1 = 0.998$) as well as with the net plankton ($r_1 = 0.957$). At Site 2 (peat bog), copepod density exhibited relatively higher abundance during the spring and depicted its maxima in March during both years (33 n/l and 27 n/l respectively). Further, low abundance was seen during the monsoon and recorded identical annual ranges and mean values. On the other hand, at Site 3 (paddy-field), significant variation in copepod abundance was indicated by ANOVA between two years of study ($F_{1, 11} = 4.972$, $P < 0.05$) and registered wider range in second year between 6-55 n/l (18 ± 14 n/l) compared to a narrow range and low mean abundance of 5-15 n/l (8 ± 3 n/l) during the preceding year. Further, relatively higher abundance was observed in the pre-paddy and early paddy seasons and recorded distinct peak in April (55 n/l) during the second year.

Copepods comprised between 17.35-92.44 % ($47.21 \pm 28.4\%$) at Site 1 (pond) and were numerically dominant between February-July during the first year and February-March as well as during September (29%) and January (58.8%) during the second year. On the other hand, at Site 2 (peat bog), it ranged between 8.45-41.77% ($20.54 \pm 8.3\%$) and was dominant only between February-March during the first year and during October (24.5%)

of the second year. A narrow range of percentage composition in the paddy-field i.e., between 8.57-30 % ($17.58 \pm 8.3\%$) was observed and exerted its dominance only between April-May (39.6-40.5%) of the second year.

Amongst the members of this group, *Tropocyclops* sp. was recorded in quantitatively significant number at Site 1 (pond) and ranged between 4-750 n/l, while it varied with significantly narrow ranges and low mean densities at other two sites i.e., between 3-20 n/l in the peat bog (Site 2) and 3-32 n/l in the paddy-field (Site 3). Monthly density variations followed unimodal pattern at all sites with peak density recorded during March in first year at Sites 1 and 2 and during May in the paddy-field, thereby depicting its higher abundance during spring to early summer. Other quantitatively important species was *Eucyclops* sp. and was observed more abundantly at Site 1 (0-20 n/l) and rarely at Site 2 (0-4 n/l). Further, at Site 2, species of *Diaptomus* (Calanoida) occurred (0-14 n/l) occasionally. Besides, nauplius larvae were recorded in significant density in the pond (0-200 n/l) and at low density in the peat bog (1-12 n/l) and paddy-field (0-18 n/l). The presence of the nauplius larvae indicated active reproductive phase of these crustaceans as also reported by Das *et al.* (1996), Sharma and Hussain (2001) and Sharma and Lyngskor (2003). However, high abundance of these larvae at Site 1 (pond) is significantly higher than the cited reports.

Copepods also registered direct correlation with total hardness ($r_2 = 0.508$), calcium ($r_2 = 0.543$) and sodium ($r_2 = 0.490$) at Site 2 and with total hardness ($r_3 = 0.609$), magnesium ($r_3 = 0.654$), chloride ($r_3 = 0.410$) and silicate ($r_3 = 0.576$) at Site 3. On the other hand, inverse relationship was observed with pH at Site 1 ($r_1 = -0.491$). Further, this group also exhibited significant correlations with other biotic factors including Cladocera ($r_2 = 0.412$, $r_3 = 0.712$), Ostracoda ($r_3 = 0.638$) and Chlorophyceae ($r_1 = 0.548$, $r_3 = 0.423$); and inverse with Bacillariophyceae ($r_1 = -0.485$) and Rhizopoda ($r_1 = -0.410$).

The other groups of zooplankton included Ostracoda, which was represented only by a single species of *Cypris* sp. Abundance of Ostracoda ranged between 0-3 n/l (1 ± 1 n/l), 0-3 n/l (2 ± 1 n/l) and 0-3 n/l (1 ± 1 n/l) at Sites 1-3 respectively. It was observed occasionally at Site 2 and Site 3, but it was recorded only during the rainy season at Site 1 as also indicated by its positive correlation with rainfall ($r_1 = 0.624$). Further, it registered positive correlation with total hardness ($r_1 = 0.478$), magnesium ($r_1 = 0.552$) and calcium ($r_1 = 0.412$) in the pond. Ostracoda also depicted positive correlations with biotic factors

including zooplankton ($r_2 = 0.421$) at Site 2 and Gastrotricha ($r_1 = 0.501$) at Site 2. Similarly, a species of Nematoda was recorded at all sites during the present study. It depicted their monthly variations between 0-4 n/l, 1-2 n/l and 0-6 n/l at Site1-3 respectively and occurred occasionally. It indicated a positive correlation with chloride ($r_2 = 0.456$, $r_3 = 0.410$) and inverse relationship with potassium ($r_2 = -0.467$) and sulphate ($r_2 = -0.515$). Gastrotricha, another group of zooplankton documented, was represented by *Chaetonotus* sp. and was recorded only in the pond and the paddy-field. It was seen occasionally with low abundance i.e., between 0-3 n/l in the pond and 0-2 n/l in the paddy-field. It registered a positive correlation with water temperature ($r_1 = 0.405$), free CO₂ ($r_1 = 0.844$), chloride ($r_1 = 0.418$) as well as with Rotifera ($r_1 = 0.431$) and Ostracoda ($r_1 = 0.501$) at Site 1 (pond).

III. LIMNOLOGICAL RELATIONSHIPS

Simple (linear) correlations: The present study depicted significant variations in the impact of recorded abiotic factors on different biotic community at all study sites. At Site 1 (pond), net plankton registered significant correlations with three abiotic factors namely, direct with phosphate and total dissolved solids and inversely with pH in the pond. Similarly, at Site 2 (peat bog), it was directly influenced by rainfall and inversely by transparency and specific conductivity. On the other hand, only water temperature influenced the net plankton density inversely at Site 3 (paddy-field). Further, six and four abiotic parameters at Sites 1 and 2 respectively influenced phytoplankton abundance, including direct correlations with pH and dissolved oxygen at Site 1 and with only rainfall at Site 2. On the other hand, inverse relationships were recorded with water temperature, rainfall, specific conductivity and sulphate at Site 1, while transparency, specific conductivity and total hardness influenced net plankton density at Site 2. Contrastingly, in the paddy-field, the indirect impact of only two abiotic factors including water temperature and rainfall was observed. Further, the zooplankton community in the pond (Site 1) was influenced positively by three factors viz., calcium, sulphate and total dissolved solids and inversely by pH. On the other hand, only total hardness registered indirect significant correlation with zooplankton at Site 2 (peat bog), while three factors namely, total hardness, potassium and chloride directly correlated with this biotic group at Site 3 (paddy-field).

Of the recorded groups, Cyanophyceae registered significant correlations with maximum of six abiotic parameters at Site 1; Dinophyceae at Site 2 was significantly

influenced by 10 abiotic factors and Euglenophyceae at Site 3 (paddy-field) was positively influenced by all hardness factors including free CO₂, total alkalinity, total hardness, calcium and magnesium. Amongst the zooplankton community, the maximum correlations of seven abiotic factors was recorded with Ostracoda at Site 1, while five factors correlated significantly with Rhizopoda at Site 2, of which, temperature and rainfall had direct impact and transparency, specific conductivity and sulphate, in turn had indirect impact. In the paddy-field, Copepoda registered maximum number of correlations, i.e., with four abiotic factors viz., total hardness, magnesium, silicate and chloride, while fewer correlations were shared by the abiotic factors of this ecosystem with other communities.

On the other hand, of all the abiotic parameters, pH assumed most important role at Site 1 (pond) as it showed significant correlation with six communities including direct with phytoplankton and indirect with net plankton and zooplankton. Similarly, at Site 2, rainfall was an important factor for six communities including, net plankton, phytoplankton, Chlorophyceae, Cyanophyceae, Dinophyceae as well as Rhizopoda and registered positive correlations with all the above communities. Similarly, in this peat bog, transparency indicated inverse correlations with several biotic factors including phytoplankton, Chlorophyceae, Cyanophyceae, Dinophyceae as well as Rotifera and Rhizopoda, thereby, indicating the importance of higher light penetration for these communities. On the other hand, in the paddy-field (Site 3), total hardness, registered positive correlations with zooplankton and copepods and indirect with Bacillariophyceae, Euglenophyceae and Ostracoda. The second important factor, as indicated by significant correlations, was water temperature in this ecosystem, which in turn registered positive correlation with only Rotifera and inverse with net plankton, phytoplankton and Cyanophyceae. In brief, greater impact of individual abiotic factors was noticed at Sites 1 and 2 since out of 280 instances of correlations computed 53 and 55 instances respectively assumed significance, while in the paddy-field out of 304 instances of correlations computed only 34 were significant.

Multiple Regressions:

The multiple regression of net plankton (Y_N), phytoplankton (Y_P) and zooplankton (Y_Z) with twenty abiotic factors viz. water temperature (x_1), rainfall (x_2), transparency (x_3), specific conductivity (x_4), pH (x_5), dissolved oxygen (x_6), free CO₂ (x_7), total alkalinity

(x_8), total hardness (x_9), calcium (x_{10}), magnesium (x_{11}), sodium (x_{12}), potassium (x_{13}), chloride (x_{14}), sulphate (x_{15}), phosphate (x_{16}), nitrate (x_{17}), silicate (x_{18}) dissolved organic matter (x_{19}) and total dissolved solids (x_{20}) at Site1 (pond) accounted for 73% of net plankton density variations, while the above 20 abiotic factors at Site 2 (peat bog) accounted for 95% of the variations. Similarly at Site 3 (paddy-field), above nineteen abiotic factors (transparency not applicable) accounted for 85% of net plankton density variations. On the other hand, cumulative impact of 17 abiotic factors with step-wise regression explained for 88% of net plankton density variations in the pond, indicating their greater cumulative impact on this community than all 20 parameters together. Further, step-wise regression with 10 factors (x_1 - x_{10}) accounted for 56% of variations in the pond. On the other hand, at Site 2 (peat-bog) the stated 10 factors accounted for 81% of variations, while just only four abiotic factors (x_1 - x_4) i.e. water temperature, rainfall, specific conductivity and pH accounted for a high cumulative impact of 62% of net plankton variations, thereby, indicating the most profound impact of these four factors on net plankton density. On the other hand, in the paddy-field, step-wise regression of 10 abiotic factors accounted for 64% of net plankton density variations. High cumulative impact of abiotic factors on net plankton abundance in the peat bog concurred with earlier reports of Sharma (1995), Jyrwa (1996) and Sharma and Lyngdoh (2003). However, the present finding is marginally lower in the pond while it is significantly lower in the paddy-field than the above cited reports.

Similarly, cumulative impact of 20 abiotic factors on phytoplankton density was 92% and 95% at Sites 1 and 2 respectively. However, 19 abiotic factors combinedly accounted for only 84% of density variations of phytoplankton communities in the paddy-field. On the other hand, the step-wise regression of recorded 10 abiotic factors (x_1 - x_{10}) explained for 61% of density variations in the pond, while in the peat bog, the stated factors explained for 83%. However, just as in the case of net plankton, the cumulative impact of four of the parameters viz. water temperature, rainfall, transparency and specific conductivity was up to 63% on phytoplankton density variations. On the other hand, in the paddy-field, cumulative impact of 10 factors was 69% and just seven abiotic parameters (x_1 - x_7) were 62% on the density variations of phytoplankton.

Regarding zooplankton, all twenty abiotic factors combinedly accounted for 96% of its density variations at Site 1 (pond) and 99% at Site 2 (peat bog), while in the paddy-field stated 19 abiotic factors explained for 96% of the variations. However, the step-wise

regression of ten factors accounted for 79% and eight factors accounted for 64% of density variations at Site 1. In the peat bog, stated 10 factors accounted for 74%, while nine factors explained for 72% and further regression substantially decreased the cumulative impact below 60%. On the other hand, in the paddy-field, ten abiotic factors accounted for only 58% of the density variations. Overall high cumulative impact of abiotic factors on phytoplankton and zooplankton abundance at Site 1 (pond) and Site 2 (peat bog) broadly concurred with the reports of Sharma (1995), Sharma and Hussain (2001), Sharma and Lyngskor (2003) and Sharma and Lyngdoh (2003). However in the paddy-field, it was lower than the cited reports.

Referring to individual sampling sites, net plankton registered impact range of 55-73% at Site 1, followed by 64-85% at Site 3 and 81-95% at Site 2 with 10-20 of the stated abiotic factors. Similarly, phytoplankton registered impact range of the stated abiotic factors at Site 1 (61-92%) > Site 3 (70-84%) > Site 2 (83-95%) while the impact range of abiotic factors on zooplankton density exhibited Site 3 (58-96%) > Site 1 (79-96%) > Site 2 (74-99%) indicating wider ranges of impact on net plankton and phytoplankton at Site 1 (pond) while on zooplankton at Site 3 (paddy-field). On the other hand, Site 2 (peat bog) registered narrow ranges of cumulative impact of 10-20 of the abiotic parameters and depicted maximum cumulative impact of the abiotic factors on all three main planktonic groups. On the other hand, least impact was seen in the paddy-field, thereby, indicating the role of other factors including human interventions in this ephemeral ecosystem.

Analysis of variance (ANOVA): Significant variations are indicated by ANOVA between sites as well as between months. While eight of the recorded abiotic factors depicted significant variations between months as well as between the sampling sites, Cladocera abundance and the species richness of copepods indicated variations in both the cases. In addition, most of the recorded abiotic parameters (16 out of 20) exhibited significant variations between the sites. Similarly, eight biotic components viz., phytoplankton, zooplankton, Chlorophyceae, Bacillariophyceae, Euglenophyceae, Rotifera, Copepoda and Rhizopoda indicated significant variations in their abundance as well as in their species richness between the sites. These findings clearly indicated the contrasting ecological characteristics of the sampled biotopes. On the other hand, ANOVA computed between two years of study indicated relatively fewer significant variations of the abiotic and biotic attributes. At Site 1 (pond), total hardness, magnesium and sulphate indicated significant

variations between the two years, while all the recorded biotic components indicated insignificant variations. In the peat bog (Site 2), six abiotic parameters viz., total hardness, magnesium, sodium, phosphate, silicate and dissolved organic matter varied significantly between the two annual cycles of the study period, while only net plankton, phytoplankton and Cladocera abundance indicated significant variations between the two years. Similarly in the paddy-field (Site 3), ANOVA exhibited significant annual variations of only three abiotic factors namely, pH, potassium and magnesium and three biotic communities namely, net plankton, Chlorophyceae and Copepoda abundance. The above results therefore indicated maximum annual variations of the recorded ecological factors in the peat bog and minimum variations in the pond.

IV. CONCLUSION

In view of complete lack of knowledge on limnology in general and planktonic composition, diversity and their related ecological attributes in particular from Bhutan, present pioneering study was carried out between February 2000-January 2002. To sum up, most of the sampled water bodies depicted sub-tropical nature, their waters ranging from typically acidic to circum-neutral to slightly alkaline and with poor to moderate mineral contents. Further, the waters were mostly well oxygenated and moderately hard to soft confirmed by methyl orange alkalinity and total hardness as well as by low calcium, magnesium and chloride contents. In addition, three regularly monitored biotopes in eastern Bhutan exhibited low nutrient contents viz. phosphate, nitrate and sulphate but relatively high silicate as well as low to moderate dissolved organic matter, total dissolved solids, sodium and moderate potassium. However, the three biotopes differed in some of their abiotic attributes with pond (Site 1) exhibiting least ionic concentration, circum-neutral to slightly alkaline waters, moderate dissolved oxygen and free carbon dioxide. Peat bog (Site 2), on the other hand, showed moderate ionic concentration, depicted its typical acidic nature, poor oxygenation, consistently high free CO₂ and low silicate. Paddy-field (Site 3) in turn, exhibited highest ionic concentration, wider range of pH (acidic to mildly alkaline) and well-oxygenated water with highest silica concentration among three ecosystems.

Referring to composition of net plankton, three selected ecosystems registered fairly rich diversity of 120 taxa with six groups of phytoplankton (47 taxa) and seven groups of

zooplankton (73 taxa) in all. However, individual ecosystems exhibited significant variations in their planktonic diversity with paddy-field showing highest number of net plankton, phytoplankton as well as zooplankton among three sites.

Phytoplankton richness consisted of Chlorophyceae (20 species) > Bacillariophyceae (15 species) > Cyanophyceae (6 species) > Euglenophyceae (3 species) > Dinophyceae (2 species) > Chrysophyceae (1 species) in all with the first four recorded at all sites, while Dinophyceae at Site 2 and Site 3 and Chrysophyceae only in the latter. In addition, Site 1 showed qualitative dominance by diatoms over other groups while the green algae was predominant in other two sites. Maximum differences in their phytoplankton community occurred between pond and paddy-field (60% similarity). Of the recorded taxa, *Spirogyra* sp. was perennial at all sites, while *Volvox* sp., *Cymbella* sp., *Fragilaria* sp. and *Navicula* sp. made regular appearance in pond. *Desmidium* sp., *Fragilaria* sp., *Navicula* sp., *Pinnularia* sp. and *Oscillatoria* sp. in peat bog and *Pediastrum* sp., *Cymbella* sp., *Navicula* sp. and *Pinnularia* sp. in the paddy-field were relatively more perennial. Furthermore, maximum heterogeneity in phytoplankton community was seen in the peat bog among three sites.

On the other hand, zooplankton consisted of Rotifera (38 species) > Cladocera (19 species) > Rhizopoda (9 species) > Copepoda (4 species) > Ostracoda = Nematoda = Gastrotricha (1 species each) in all sites. Species richness was highest in paddy-field (54 species), followed by pond (51 species) and least in peat bog (49 species). Percentage similarity indicated maximum heterogeneity between communities of pond and peat bog (57% similarity) and greater homogeneity between that of pond and paddy-field (69% similarity). Among recorded groups, Rotifera was qualitatively most dominant in all three biotopes and registered maximum richness in paddy-field. Most of the recorded zooplankton taxa indicated their rare occurrence in all three ecosystems except few more perennial species namely, *Tropocyclops* sp. at all sites; *Testudinella patina* in pond; *Diffugia* sp. and *Simocephalus serrulatus* in peat bog and *Euchlanis dilatata*, *Pleuroxus similis* and *Alona costata* in paddy-field.

In addition, Rotifera diversity in all sampled biotopes in Bhutan in general and eastern Bhutan in particular indicated total of 60 species comprising of 28 genera and 17 families representing mostly littoral fauna owing to mostly shallow and weedy habitats. Of the recorded taxa, 18 species (30%) comprised of lecanids, 70% of all comprised

cosmopolitan, 11 species were of sub-tropical distribution and 5 belonged to acidophilic elements. Further, occurrence of a typical *Keratella* sp. and two species of rare regional distribution namely, *Platyias polyacanthus* and *Monommata longiseta* characterized the present records. Besides, *Lecane scutata*, an arctic temperate taxa and *Trichocerca cylindrica*, a palearctic and nearctic species comprised the present rotifer fauna.

On the other hand, monthly abundance of net plankton recorded wide range in the pond following a notable copepod bloom of *Tropocyclops* sp. in early summer thereby exhibiting dominance by zooplankton at this site. On the other hand, peat bog and the paddy-field showed dominance by phytoplankton with highest species diversity in peat bog followed by paddy-field and least in the pond. Similarly, relatively higher dominance was seen in peat bog and paddy-field owing to larger number of quantitatively dominant species with maxima in the later site coinciding with *Nostoc* sp. bloom during winter of second annual cycle.

Further, the diatoms were quantitatively dominant in pond and paddy-field corresponding with higher silicate content while Chlorophyceae followed by Cyanophyceae occurred predominantly in the peat bog. Of the recorded species, *Navicula* sp. was predominant at Site 1 and Site 3 and the filamentous algae namely, *Spirogyra* sp. at Site 2. On the other hand, among green algae, highest abundance of desmids was seen in the paddy-field (37%) and the least in peat bog (16%).

Zooplankton abundance in the pond was significantly high, particularly in first year thereby exhibited high dominance corresponding with copepod bloom. Moderate species diversity of zooplankton was indicated at all sites with narrow monthly variations and comparatively higher mean value in paddy-field. However, evenness indicated fair equitability of zooplankton abundance at all sites.

Of the recorded groups, pond exhibited distinct dominance by Copepoda while the peat bog and the paddy-field exhibited almost identical quantitative importance of recorded four main groups with slightly higher abundance of Cladocera at Site 2 and of Rotifera at Site 3. Of the recorded taxa, *Tropocyclops* sp. was most abundant at all sites and distinctly in the pond.

Among three sites, greater impact of abiotic factors was recorded on biotic components in the pond followed by peat bog and least in the paddy-field (Site 3). In addition, step-wise regression indicated wider ranges of impact of 11-20 abiotic factors on

net plankton and phytoplankton in pond and on zooplankton in paddy-field. On the other hand, peat bog received maximum cumulative impact of abiotic factors on all three main planktonic groups, while the least was in the paddy-field.

ANOVA indicated significant variations in eight abiotic factors between months as well as between sites and in 16 out of 20 recorded abiotic factors between the sites. Similarly, eight biotic components including phytoplankton and zooplankton varied significantly between sites in their abundance as well as species richness, thereby highlighting on the contrasting ecological characteristics of the three biotopes.

In short, the sampled lentic ecosystems mostly of eastern Bhutan depicted acidic to slightly alkaline soft waters of low to moderate ionic concentration and comprised considerable plankton diversity with sixty species of rotifers consisting mainly of semi-planktonic and littoral fauna with few taxa of biogeographical and ecological importance including a new *Keratella* sp. Three regularly monitored ecosystems in eastern part of the country, on the other hand, differed in their basic ecological attributes with the pond (Site 1) exhibiting its circum-neutral waters of relatively high silica content, which exhibited a bloom of copepods with significant annual variations indicating its unstable condition owing to the influence from its catchments. Poorly oxygenated, the acidic peat bog (Site 2) with low nutrients in general showed high abundance of filamentous algae, high diversity and dominance as well as evenness of phytoplankton. On the other hand, the ephemeral paddy-field (Site 3) exhibited comparatively higher ionic concentration, total alkalinity, hardness as well as calcium, potassium and sodium, due to regular ploughing and puddling hence discharging ions and minerals into the surface water and also recorded highest qualitative as well as quantitative abundance of net plankton, phytoplankton and zooplankton among three sampled biotopes.

SUMMARY

The kingdom of Bhutan, characterized by mountainous terrain with an intricate network of drainage system and rich watershed, is endowed with diversity of lentic ecosystems including glacial lakes, ponds, wetlands and paddy-fields scattered throughout different climatic regimes of the country. However, there is no single limnological work in Bhutan that deals with biological diversity in water bodies or temporal variations in abiotic attributes in any particular aquatic biotope. In light of the above lacunae, present pioneering study carried out between February 2000-January 2002 brings into limelight the water quality, species richness of net plankton, zooplankton, phytoplankton, percentage similarities, richness, abundance, diversity, dominance, evenness and other related ecological attributes in three selected ecosystems in eastern Bhutan with emphasis on biodiversity of zooplankton in east Bhutan in general and Rotifera diversity in all sampled biotopes in different parts of the country in particular. The results obtained are summarised below:

ABIOTIC FACTORS

Air temperature at three regular study sites viz. Site 1 (pond), Site 2 (peat bog) and Site 3 (paddy-field) ranged between 13.1-28.9° C ($18.4 \pm 4.3^\circ$ C), 10.5-28.8° C ($18.2 \pm 5.0^\circ$ C) and 9.4- 28.3° C ($21.2 \pm 5.7^\circ$ C) respectively. Similarly water temperature ranged between 10.5-24.9° C ($17.2 \pm 4.0^\circ$ C), 9.1-26° C ($16.4 \pm 4.9^\circ$ C) and 9.0 - 25.6° C ($19.7 \pm 4.9^\circ$ C) respectively without notable variations between the two annual cycles of the study period. ANOVA indicated significant variations between months ($F_{23, 46} = 12368$, $P < 0.01$) as well as between sites ($F_{2, 46} = 15.687$, $P < 0.01$). The recorded annual variations depicted sub-tropical nature of the sampled biotopes. This generalisation was also confirmed by mean temperature at other sampled water bodies (Sites 4-24) where air and water temperature ranged between 2.0-32.0° C ($18.0 \pm 8.0^\circ$ C) and 1.1.0-29.5.0° C ($17.2 \pm 7.97^\circ$ C) respectively ranging from temperate condition in high altitude lakes to sub-tropical at the foothills. In addition, highly significant positive correlation between air and water temperature at all three regularly monitored water bodies indicated their shallow nature.

Rainfall, mainly owing to the southeast monsoon, varied with marginally wider range and higher mean at Sites 1 and 2 i.e., between 5.0-225.0 mm (100.4 ± 84.0 mm). At

Site 3, it ranged between 0.7-364.0 mm (94.9 ± 108.8 mm) and recorded higher rainfalls between May-September while the winters were relatively dry. ANOVA exhibited significant variations in rainfall between the sites ($F_{1, 23} = 20.715$, $P < 0.01$). Total annual rainfall was recorded higher in first year i.e., 1250 mm in first year and 1160.40 mm during the second year at Sites 1 and 2 and 1275 mm and 1002.1 mm respectively at Site 3. Rainfall exerted its direct influence on specific conductivity and sulphate at Site 1 and on calcium at Site 2, thereby, indicated the influx of ions along with surface soil and debris. The later fact also reduced light penetration, which is also affirmed by inverse relationships with transparency at both sites.

Transparency, on the other hand, ranged between 65.0-110.0 cm (89.6 ± 14.1 cm) in the pond and between 55.0-95.0 cm (79.5 ± 12.7 cm) in the peat bog. ANOVA indicted significant variations between two sites ($F_{1, 23} = 719.165$, $P < 0.01$). Generally low penetration of light could be owing to small nature of water bodies and the shadowing effect of canopy of vegetation and macrophytes around these water bodies. Lesser transparency was recorded during rainy season and higher in winter months as also indicated by high negative correlation with rainfall at both sites. Transparency registered positive relationship with dissolved oxygen and inverse with specific conductivity, free CO_2 and alkalinity at Site 1.

pH varied with narrow ranges at all sites, thereby indicating buffered condition. ANOVA showed significant variations in pH between months ($F_{23, 46} = 2.088$, $P < 0.05$) as well as between sites ($F_{2, 46} = 19.061$, $P < 0.01$). It ranged between 6.53-7.8 (6.91 ± 0.34) in pond (Site 1) depicting slightly acidic-alkaline character; between 5.69-6.58 (6.17 ± 0.27) in the peat bog (Site 2) showing its typical 'acidic nature' and between 6.21-7.41 (6.75 ± 0.27) in the paddy-field depicting acidic to slightly alkaline conditions. Further, in the pond, pH increased slightly above mean after monsoon (pH 7.2) in first year and significantly during the second year (pH 7.8). On the other hand, in the peat bog water was acidic throughout the study period. Paddy-field depicted significant annual variations in pH ($F_{1, 11} = 4.585$, $P < 0.05$) and exhibited wider range and higher mean (pH 6.9) during first year in comparison to comparatively more acidic condition of the second year. In addition, pH values at all other sampled water bodies ranged broadly between 6.24-8.29 (6.8 ± 0.5) depicting acidic nature of two of the sampled sites; circum-neutral character of most water

bodies (pH 6.5-7.5) and alkaline nature of the sewage stabilization pond, a paddy-field and a fish pond. Waters in eight of the sites fall within 'acidophilus' (pH 5.5-6.45) and two in alkaliphilus categories (pH 7.6 and 8.29). pH shared inverse relationships with specific conductivity, total hardness, sulphate and phosphate at Site 1, with potassium and phosphate at Site 2 and with total alkalinity, magnesium and potassium at Site 3.

Specific conductivity was generally low at all sites and ranged between 22-62 $\mu\text{S}/\text{cm}$ ($33.4 \pm 10.5 \mu\text{S}/\text{cm}$) in the pond, 17-62 $\mu\text{S}/\text{cm}$ ($43.4 \pm 14.8 \mu\text{S}/\text{cm}$) in the peat bog and 33-88 $\mu\text{S}/\text{cm}$ ($52.8 \pm 15.2 \mu\text{S}/\text{cm}$) in the paddy-field. ANOVA indicated significant variations in specific conductivity between months ($F_{23, 46} = 2.701$, $P < 0.05$) as well as between sites ($F_{2, 46} = 19.061$, $P < 0.01$). It was relatively higher during dry months and indicated maxima during summer at all sites and low during monsoon owing to dilution effect of the rainwater. Of the three sites, paddy-field depicted higher mean owing to ploughing and thereby, leaching of ions into the surface water. In addition, all other sampled biotopes registered wider range of the ionic concentration and in turn ranged between 12-500 $\mu\text{S}/\text{cm}$ ($71.4 \pm 99.2 \mu\text{S}/\text{cm}$) with the highest in a eutrophic sewage stabilization pond (Site 5) and relatively high in three of the sampled sites representing a fish pond, an ephemeral pond and a river-fed recreational pond. However, rest of the natural water bodies depicted generally low mineral ions, which, in turn ranged between 16-142 $\mu\text{S}/\text{cm}$ ($52.8 \pm 38.8 \mu\text{S}/\text{cm}$) thereby indicating soft-water character of the studied biotopes. Further, in the regularly monitored sites, direct correlations of specific conductivity was computed with sulphate, rainfall, calcium and nitrate in the pond (Site 1) and with total alkalinity, potassium, sodium, sulphate and dissolved organic matter at Site 2, thereby indicating the role of these factors in the ionic content.

Significant variations in dissolved oxygen were seen between months ($F_{23, 46} = 2.877$, $P < 0.01$) as well as between sites ($F_{2, 23} = 26.394$, $P < 0.01$). Greater oxygenation was seen in paddy-field (Site 3) which ranged between 2.4-13.6 mg/l ($7 \pm 2.5 \text{ mg}/\text{l}$) followed by pond (Site 1) with 2.4-10.8 mg/l ($5.38 \pm 2.3 \text{ mg}/\text{l}$) and the least in the peat bog (Site 2) i.e., between 1.2-9.6 mg/l (3.37 ± 1.78). Notably low dissolved oxygen in the peat bog (mean 27% saturation) indicated its utilization for decomposing high quantity of floral debris. On the other hand, higher oxygenation observed during pre- and post monsoon months at Sites 1 and 2, is affirmed by significant inverse relationships with rainfall.

Further, relatively higher oxygenation in cleaner water was indicated by positive correlation between dissolved oxygen and transparency. Dissolved oxygen at other sampled biotopes, in turn, varied with wider range i.e., between 2.3-16.0 mg/l (7.3 ± 3.7 mg/l). While some of the shallow ecosystems including paddy-fields showed lower values, eutrophic sewage stabilization pond recorded a low of 2.4 mg/l due to high rate of decomposition of algal bloom. On the other hand, high dissolved oxygen content in deeper glacial lakes was apparently due to greater diffusion of oxygen at low temperature.

Free carbon dioxide was registered throughout the study period at Site 1 (pond) and Site 2 (peat bog) and ranged 3.2-2.4 mg/l (7.1 ± 4.3 mg/l) and 11.2-65.0 mg/l (19.5 ± 11.1 mg/l) respectively thereby reflecting its poor autotrophic uptake in those ecosystems. However, at Site 3 (paddy-field), it ranged between 0.0-20.0 mg/l (5.4 ± 4.0) and was not recorded in October 2000, apparently owing to greater rate of photosynthesis during that month which corresponded to high phytoplankton density. ANOVA indicated significant variations between all sites ($F_{2, 46} = 32.399$, $P < 0.01$) as well as significant annual variations in peat bog ($F_{1, 11} = 9.65$, $P < 0.01$). Free CO₂ in other sampled water bodies ranged between 2.0-19.5 mg/l (6.55 ± 4.55 mg/l) with maximum observed in a shallow and weedy pond at 1850 m ASL and minimum in another pond at the foothills. It indicated significant positive relationships with total alkalinity at Site 1, with calcium and sulphate at Site 3 and inverse with total hardness at Site 1.

Total alkalinity (bicarbonate) was generally low at all sites and ranged between 17.0-30.0 mg/l (24.8 ± 3.6 mg/l), 11.0-36.0 mg/l (22.2 ± 7.8 mg/l) and 16.8-40.0 mg/l (27.9 ± 6.4 mg/l) respectively. ANOVA indicated significant variations between the sampled sites ($F_{2, 46} = 5.245$, $P < 0.01$). While low alkalinity was observed during rainy seasons at Site 1 (pond) and Site 2 (peat bog) owing to dilution effect, greater leaching out of ions resulted in higher alkalinity during paddy seasons at Site 3 (paddy-field). However, at all other sampled water bodies total alkalinity ranged between 13.1-240.0 mg/l (40.9 ± 47.1) with 'very hard' in eutrophic sewage stabilisation pond (240 mg/l) to moderately hard at Site 13 (80 mg/l) = Site 10 (80 mg/l) > Site 19 (68 mg/l) > Site 15 (64 mg/l) > Site 6 (40 mg/l) = Site 18 (40 mg/l) and 'soft water' at all other 17 biotopes (70% of the total sampled sites) with mean value of 21.7 ± 7.2 mg/l. Six other ecosystems with moderate hard water ranged from a river-fed recreational pond to occasionally limed fishponds.

Similarly, total hardness showed soft-water characteristics of Sites 1-3 and ranged between 11.0-26.0 mg/l (16.4 ± 3.8 mg/l), 10.0-34.0 mg/l (18.3 ± 5.7 mg/l) and 4.0-40.0 mg/l (22.0 ± 7.5 mg/l). Further, ANOVA indicated significant variations between months ($F_{23, 46} = 2.326$, $P < 0.05$) as well as between sites ($F_{2, 46} = 8.288$, $P < 0.01$). In addition, significant variations were also noted between their annual values at Site 1 ($F_{1, 11} = 6.664$, $P < 0.05$) as well as at Site 2 ($F_{1, 11} = 5.810$, $P < 0.05$), while they were identical in the paddy-field. It ranged more widely at all other sampled water bodies i.e., between 7.0-76.0 mg/l (24.1 ± 18.3 mg/l) depicting a 'very soft' nature of eight of the diverse ecosystems located at varied altitudes. Besides, moderately 'hard water' was seen at three sites and all other 13 sites depicted 'soft water' characteristics. Significant positive correlations of total hardness are indicated with magnesium and sodium at all sites, potassium at Sites 1 and 2 and with calcium at Site 1.

Sites 1-3 exhibited 'calcium poor' water and ranged between 2.9-8.4 mg/l (4.9 ± 1.5 mg/l), 3.2-8.4 mg/l (5.6 ± 1.6 mg/l) and 4.2-13.7 mg/l (7.2 ± 2.6 mg/l) respectively. Significant variations in calcium content were noted between the sites ($F_{2, 46} = 7.698$, $P < 0.01$), with maxima in spring to early summer in pond, during autumn in peat bog and during early paddy season in paddy-field. However, in other water bodies it ranged more widely between 2.5-41.0 mg/l (9.9 ± 10.0 mg/l) with highest in the sewage stabilization pond. Further, Site 19 (29.4 mg/l) > Site 15 (27.3 mg/l) represented 'calcium rich' condition; Site 14 > Site 10 > Site 18 = Site 6 had waters with 'medium' calcium content (12.6-21 mg/l) and the remaining seventeen sites (70%) indicated 'calcium poor' (2.52-7.17 mg/l) conditions.

Similarly, magnesium content was low at all sites and ranged between 0.87-4.53 mg/l (2.64 ± 1 mg/l), 1.13-8.11 mg/l (3.2 ± 1.54 mg/l) and 1.6-8.34 mg/l (3.6 ± 1.77 mg/l) at Site 1-3 respectively. ANOVA indicated significant variations between months ($F_{23, 46} = 2.109$, $P < 0.05$) as well as between sites ($F_{2, 46} = 3.584$, $P < 0.05$). Further, significant annual variations were also indicated by ANOVA at all sites (Site 1: $F_{1, 11} = 5.027$; Site 2: $F_{1, 11} = 5.940$; Site 3: $F_{1, 11} = 6.865$, $P < 0.05$). Similarly, at other sites, magnesium content ranged between 0.6-8.52 mg/l (3.42 ± 2.38 mg/l) and was lesser than calcium in all cases. In addition, magnesium contributed significantly to total hardness at all three sites affirmed

by their high positive correlations. Magnesium also positively correlated with specific conductivity and total alkalinity in the paddy-field.

Sodium content was low and ranged between 1.17-6.68 mg/l (3.54 ± 1.58 mg/l), 2.0-6.8 mg/l (4.0 ± 1.48 mg/l) and 1.0-8.35 mg/l (4.46 ± 1.9 mg/l) at Sites 1-3 respectively with marginal differences in their annual ranges and mean values. However, ANOVA exhibited significant variations between months ($F_{23, 46} = 3,383$, $P < 0.01$) as well as between study sites ($F_{2, 46} = 3.260$, $P < 0.05$). Higher sodium was recorded in dry months owing to evaporation and subsequent concentration of this alkaline earth metal. It registered significant positive correlations with potassium and total hardness and inverse with pH at Site 3. Similarly, potassium, another micronutrient, was moderate in its content at all three sites and ranged between 2.5-9.25 mg/l (5.38 ± 1.74 mg/l), 1.75-13.5 mg/l (5.29 ± 3.4 mg/l) and 2.0-8.0 mg/l (4.06 ± 1.782 mg/l) respectively with wider ranges and higher mean values registered during the second year at Sites 1 and 3. Further potassium was low during late monsoon at all sites as also shown by significant variations between months ($F_{23, 46} = 1.901$, $P < 0.05$).

Chloride content registered low mean values at Sites 1-3 and ranged between 2.5-6.6 mg/l (4.2 ± 1.2 mg/l), 2.8-6.2 mg/l (4.7 ± 0.9 mg/l) and 2.0-7.0 mg/l (4.6 ± 1.2 mg/l) respectively, reflecting lack of organic pollution. At all other sampled ecosystems, chloride content ranged between 2.1-42.0 mg/l (7.4 ± 8.0 mg/l) with highest in sewage stabilisation pond indicating presence of organic pollutants. However, in the rest of the water bodies it ranged between 2.1-14.0 mg/l (5.9 ± 3.2 mg/l), thereby, also indicated lack of organic pollution.

Low concentration of sulphate was recorded at all three sites, which in turn, fluctuated between 0.12-0.76 mg/l (0.41 ± 0.21 mg/l), 0.85-2.99 mg/l (1.59 ± 0.69 mg/l) and 0.92-3.059 mg/l (1.77 ± 0.65 mg/l) respectively. The documented ranges at all sites fall within the normal range of >1-30 mg/l reported to occur in freshwater. In the pond ANOVA indicated significant annual variations ($F_{1, 11} = 12.489$, $P < 0.01$) and showed higher concentration of sulphate during rainy season as also affirmed by significant positive correlation with rainfall. Sulphate also shared positive relationship with specific conductivity at Sites 1 and 2.

Phosphate was low at all sites reflecting weathered nature of the rocks. It ranged between 0.004-0.06 mg/l (0.03 ± 0.02 mg/l), 0.006-0.17 mg/l (0.05 ± 0.05) and 0.006-0.078 mg/l (0 ± 0.02 mg/l) at Site 1-3 respectively. ANOVA exhibited significant variations between months ($F_{23, 46} = 1.903$, $P < 0.05$) as well as between the sampled sites ($F_{2, 46} = 4.087$, $P < 0.05$). The observed values at Sites 1 (pond) and 2 (peat bog) showed greater concentration in early summer (April-May), apparently due to concentration of the nutrient during these dry months. At Site 3 (paddy-field), it was relatively higher in early period of paddy season and low during paddy season, which could be attributed to greater utilization of this scarce nutrient. It indicated positive correlation with total dissolved solids at Site 1.

Nitrate, another essential nutrient, was also low with monthly variations ranging between 0.009-0.17 mg/l (0.06 ± 0.003 mg/l), 0.003-0.18 mg/l (0.1 ± 0.04 mg/l) and 0.01-0.506 mg/l (0.1 ± 0.11 mg/l) at Sites 1-3 respectively without significant variations between months as well as between sampled sites ($P > 0.05$). In addition, ANOVA indicated insignificant annual variations at all sites. However, in the paddy-field greater nitrate concentration was recorded prior to cultivation and in the early paddy season due to evaporation as well as ploughing activities. In addition, relatively higher mean value was registered during the second year of study in this ecosystem.

Silicate was moderate to high and showed wide temporal variations in the pond and the paddy-field. It ranged between 2.5-62.5 mg/l (13.7 ± 13.4 mg/l) and 20.4-60.0 mg/l (20.4 ± 18.4 mg/l) respectively due to influx of weathered silts and sediments from the catchments. However, comparatively low silica was recorded in the generally nutrient poor and acidic peat bog, which in turn ranged between 2.5-15.0 mg/l (8.6 ± 3.6 mg/l). ANOVA indicated significant variations between sites ($F_{23, 46} = 4.669$, $P < 0.05$). In addition, it registered wider range and higher mean during the first annual cycle at Site 1 (pond) and varied with generally higher concentration during late summer and low in winter. Higher silica during summer at Site 3 is also supported by positive correlation with temperature. Silicate also indirectly correlated with total hardness at Site 3 and with magnesium and chloride at Site 2.

Dissolved organic matter (DOM) varied with narrow ranges between 0.24-4.5 mg/l (1.95 ± 1.25 mg/l) at Site 1 (pond) 0.9-9.6 mg/l (4.13 ± 3.1 mg/l) and 0.75-11.25 mg/l (2.92 ± 2.46 mg/l) in the other two sites respectively. ANOVA indicated significant variations

between sites ($F_{23, 46} = 5.452$, $P < 0.01$). DOM was higher during paddy seasons at Site 3, while it was higher during winter in the peat bog as well as in the pond. It positively correlated with nitrate at Sites 2 and 3, sulphate at Site 1 and silicate and conductivity at Site 2.

Similarly total dissolved solids were low and corresponded with low ionic concentrations at all sites. It ranged between 0.24-0.85 mg/l (0.49 ± 0.17 mg/l), 0.22-0.85 mg/l (0.54 ± 0.17 mg/l) and 0.24-0.58 mg/l (0.4 ± 0.11 mg/l) respectively. Further, ANOVA indicated its significant variations between sites ($F_{23, 46} = 5.151$, $P < 0.05$). Relatively higher values were recorded during winter and early summer due to concentration of the ions in the pond and the peat bog and this finding was affirmed by negative correlation with rainfall in the latter ecosystem. On the other hand, it was high during early paddy season at Site 3 coinciding with agricultural practices.

BIOTIC FACTORS

Qualitative composition

The net plankton in three sampled biotopes viz. Site 1 (pond), Site 2 (peat bog) and Site 3 (paddy-field) appeared diversified with Site 3 (89 species) > Site 1 (76 species) = Site 2 (76 species) and registered 120 species including 47 species of phytoplankton (6 groups) and 73 species of zooplankton (7 groups) in all. Further, ANOVA indicated significant variations in species richness of net plankton between months ($F_{23, 46} = 14.093$, $P < 0.01$). Monthly species richness of net plankton at Sites 1-3 ranged between 18-36 species (27 ± 5 species), 17-45 species (30 ± 7 species) and 27-42 species (35 ± 4 species) respectively with highest in the paddy-field due to its ephemeral nature and the growth of the paddy.

Phytoplankton, on the other hand, were represented by six groups namely, Chlorophyceae (20 species) > Bacillariophyceae (15 species) > Cyanophyceae (6 species) > Euglenophyceae (3 species) > Dinophyceae (2 species) > Chrysophyceae (1 species) at all sites. It exhibited Site 3 (35 species) > Site 2 (27 species) > Site 1 (24 species). ANOVA indicated significant variations in species richness of phytoplankton between months ($F_{23, 46} = 22.077$, $P < 0.01$). Percentage similarity indicated maximum heterogeneity in phytoplankton community between pond and paddy-field (60%) and maximum similarity between peat bog and the paddy-field (70%). While Bacillariophyceae was qualitatively important (12 species) group in the pond, Chlorophyceae, in turn, was dominant in the peat

bog (11 species) as well as in the paddy-field (15 species). Chlorophyceae comprised eight species of desmids (40%) and four filamentous algae in all, of which *Spirogyra* sp. was common at all sites and was recorded in most of the monthly collections. On the other hand, *Mougeotia* sp. and *Staurastrum* sp. was recorded only in the peat bog while *Oedogonium* sp., *Radiococcus* sp., *Scenedesmus quadricaudata*, *Tetraspora* sp. and *Zygnema* sp. were registered only in the paddy-field. Percentage similarities computed ranged between 21.1%-100%, 13.3%-95.2% and 24-85.7% respectively thereby indicating sizeable variations in their community structure in general and depicted maximum heterogeneity in the peat bog.

On the other hand, zooplankton, represented by 73 taxa, belonged to seven groups with Rotifera (38 species) > Cladocera (19 species) > Rhizopoda (9 species) > Copepoda (4 species) = Ostracoda (1 species) = Gastrotricha = Nematoda in all. Highest number of species was recorded at Site 3 (54 species) followed by Site 1 (51 species) and Site 2 (49 species). ANOVA indicated significant variations of zooplankton species richness between sites ($F_{2, 46} = 6.886$, $P < 0.01$). Pond and the peat bog exhibited maximum heterogeneity in their community (57% similarity). Further, percentage similarities indicated wide variation in community structure at Site 1 (20-90%) and narrow at Site 3 (37.5-90.2%).

Phylum Rotifera was qualitatively dominant at all sites with maximum diversity in the paddy-field. In addition, in all sampled biotopes, total of 60 species of rotifers were recorded and comprised of 16 families of which five families namely, Lacanidae (18 species) > Brachionidae (12 species) > Colurellidae (6 species) > Trichocercidae (5 species) were predominant. Seventy percent of total recorded rotifer fauna comprised cosmopolitan species and 11 of them of sub-tropical elements. Further, *Lecane scutata*, an arctic temperate taxa, *L. doryssa*, *Keratella cochlearis* and *Squatinella mutica* represented acidophilic elements in the generally acidic waters of the studied biotopes. Besides, a typical species of *Keratella* recorded in east Bhutan indicated its cold water affinity (2570-3150 m ASL). *Platyias polyacanthus*, a rare taxon, and *Trichocerca cylindrica* and *Monommata longiseta*, species of bio-geographical importance were also recorded from relatively wider range of alleviations.

Quantitative composition

Monthly net plankton abundance ranged widely between 93-1114 n/l (286 ± 227 n/l) at Site 1 (pond) and with narrow ranges at Site 2 (peat bog) and Site 3 (paddy-field) i.e., between 93-692 n/l (245 ± 136 n/l) and 75-663 n/l (247 ± 138 n/l). Maxima was recorded in spring (March-April) in the pond, during mid-monsoon (August) in the peat bog and in winter (December) in the paddy-field. Highest population density of net plankton in the pond was due to copepod bloom, which was significantly higher during the first year. Higher density of net plankton during pre-monsoon periods coincided with higher concentration of the nutrients in the pond. This fact was also indicated by a direct correlation with phosphate and TDS ($r_1 = 0.524$). ANOVA indicated significant annual variations in net plankton abundance at Site 2 (peat bog) as well as Site 3 (paddy field) ($F_{1, 11} = 4.812$, $P < 0.05$; $F_{1, 11} = 5.032$, $P < 0.05$ respectively) and registered higher mean in the first year while reverse trend was seen in the latter.

Phytoplankton was quantitatively dominant at Site 2 ($68.5 \pm 12.0\%$) and Site 3 ($68.2 \pm 12.1\%$) and sub-dominant at Site 1 ($48.0 \pm 27.3\%$). ANOVA indicated significant variations in phytoplankton abundance between study sites ($F_{2, 46} = 3.225$, $P < 0.05$). Monthly abundance ranged widely with highest mean in the paddy-field i.e., 43-613 (180 ± 139 n/l), closely followed by peat bog, which in turn, ranged between 55-630 n/l (179 ± 136 n/l) and depicted narrow range and low mean of 38-265 n/l (106 ± 72 n/l) in the paddy-field. While the higher abundance was recorded with single distinct maxima each year during autumn (November 2001) and early winter (December 2002) in the pond, higher density was seen during monsoon with peak in August during the first year and maxima in July during the second year in the peat bog. On the other hand, paddy-field registered higher density during autumn and early winter (October-January).

Further, phytoplankton exhibited moderate species diversity (*vide* Shannon's index) at all sites with highest in the peat bog (2.046 ± 0.589) followed by paddy-field (1.916 ± 0.46) and the least in the pond (1.860 ± 0.354). Pond depicted higher phytoplankton diversity in pre-monsoon and early monsoon periods, peat bog during early summer and the paddy-field during pre-paddy and post-paddy seasons. Low diversity during plantation and harvest activities indicated impact of agricultural practices in the paddy-field. Phytoplankton dominance *vide* Simpson's index (λ) was highest in the peat bog (0.290 ± 0.145), followed by paddy-field (0.245 ± 0.160) and the pond (0.219 ± 0.111). In the pond,

low dominance was recorded between February-August during both the years and maxima were registered in December in first year and January. In the peat bog, higher dominance was in late autumn-winter and a low between May-September in first year and between April-July in second year. Peak dominance in the paddy-field coincided with *Nostoc* sp. bloom during December of the second year. High equitability of species abundance in the community was indicated by high evenness of phytoplankton at all sites. Highest evenness was recorded in peat bog (0.908 ± 0.24) followed by paddy-field (0.825 ± 0.230) and the least in the pond (0.732 ± 0.167). While the pond registered higher evenness during spring as well as during the mid-monsoon, peat bog exhibited consistently high evenness between March-November during first year and relatively high between April-July during the second year. In the paddy-field, higher values were observed during summer.

Of the recorded groups of phytoplankton, Chlorophyceae was dominant at Site 2 (peat bog) and exhibited Chlorophyceae (90 ± 63 n/l) > Cyanophyceae (49 ± 77 n/l) > Bacillariophyceae (36 ± 34 n/l). On the other hand, Bacillariophyceae was dominant at Site 1 as well as Site 3 and in turn, depicted Bacillariophyceae (46 ± 25 n/l) > Cyanophyceae (38 ± 56 n/l) > Chlorophyceae (21 ± 12 n/l) in the pond and Bacillariophyceae (83 ± 53 n/l) > Cyanophyceae (58 ± 131 n/l) > Chlorophyceae (35 ± 23 n/l) in the peat bog. Other three groups viz. Euglenophyceae, Dinophyceae and Chrysophyceae were found to be quantitatively insignificant throughout the study period at all sites.

Among the recorded taxa, the peat bog exhibited predominance by filamentous algae viz. *Spirogyra* sp. (10-158 n/l) and *Ulothrix* sp. (0-153 n/l) which comprised 60% of Chlorophyceae density. Desmids, in turn, contributed up to 37% of green algae in paddy-field followed by 23% in the pond and least (16%) in the peat bog. ANOVA indicated significant variations in green algae between sites ($F_{2, 46} = 19.093$, $P > 0.01$). On the other hand, of the recorded diatoms, *Navicula* sp. (2-55 n/l) and *Fragilaria* sp. (0-25 n/l) in the pond (Site 1) and *Navicula* sp. (5-170 n/l) and *Pinnularia* sp. (0-25 n/l) in the paddy-field (Site 3) more perennial. Of the blue green algae, *Oscillatoria* sp. was predominant in the pond (0-180 n/l) as well as the peat bog (0-75 n/l), *Nostoc* sp. (0-500 n/l) exhibited high abundance only during the winter of second year in the paddy-field (Site 3).

Referring to the quantitative abundance of zooplankton, ANOVA showed their significant variations between sites ($F_{2, 46} = 5.246$, $P < 0.01$). In the pond the monthly density ranged between 33-1071 n/l (180 ± 243 n/l) and dominated in 13 out of 24 monthly

samples. This was due to copepod bloom in early spring reaching their peak density in April 2000 (950 n/l) and March 2001 (223 n/l). However, the copepod bloom was of lesser magnitude in the second year and ranged between 9-223 n/l (81 ± 93 n/l) against a much higher range of 6-950 n/l (187 ± 304 n/l) in the first year. On the other hand relatively narrow ranges were seen at Sites 2 and 3 i.e., between 34-123 n/l (66 ± 20 n/l) and 32-140 n/l (68 ± 27 n/l) respectively and depicted higher abundance during early spring (March) in the former site and during the period of active growth of paddy in the later. In addition, generally low abundance in the paddy-field coincided with adverse conditions created during plantation activities.

Moderate species diversity of zooplankton was indicated by Shannon's index (H') at all sites with a narrow monthly variations and high mean diversity in the paddy-field (Site 3), which ranged between 2.397-3.676 (2.904 ± 0.249), followed by relatively wider variation in the peat bog, i.e., between 1.871-3.24 (2.745 ± 0.3). However, in the pond (Site 1) it varied more widely and registered lowest mean, which in turn, ranged between 0.930-3.232 (2.306 ± 0.815). Higher zooplankton diversity was observed from summer to early winter (June-December) in the pond, during early summer (April-July) in the peat bog and during spring as well as during period of active growth of paddy in the paddy-field. On the other hand, zooplankton dominance (Simpson's index) was moderately high in the pond and ranged between 0.102-0.779 (0.360 ± 0.238) followed by low in the peat bog and the paddy-field, which, in turn, ranged between 0.037-0.267 (0.074 ± 0.046) and 0.030-0.122 (0.054 ± 0.022) respectively. High dominance in the pond broadly corresponded with the copepod bloom during the early summer. Evenness (E_1) indicated high equitability of zooplankton at all sites. However comparatively narrow ranges in the paddy-field and the peat bog were observed and in turn ranged between 0.853-1.142 (0.959 ± 0.052) and 0.729-0.967 (0.925 ± 0.049) respectively and with wide range of 0.343-1.134 (0.823 ± 0.280) in the pond. While Site 1 (pond) recorded higher richness during monsoon to mid-winter (June-January), the peat bog and the paddy-field depicted lesser monthly variations.

Of the quantitatively important groups, at Site 1 (pond), copepods were distinctly dominant and exhibited Copepoda (143 ± 227 n/l) > Cladocera (27 ± 22 n/l) > Rotifera (11 ± 4 n/l) while at Site 2 (peat bog) and Site 3 the first main groups showed only marginal differences in their contribution to total zooplankton abundance and exhibited Cladocera

(20 ± 15 n/l) > Rotifera (15 ± 6 n/l) > Copepoda = Rhizopoda (14 ± 7 n/l) in the former site and Rotifera (21 ± 3 n/l) > Cladocera (18 ± 8 n/l) > Copepoda (13 ± 11 n/l) = Rhizopoda (13 ± 5 n/l) in the latter site. In addition, of all the recorded taxa, *Tropocyclops* sp. was most abundant at all sites with distinctly high density in the pond (104 ± 174 n/l) followed by comparatively low density at Site 2 (8 ± 4 n/l) and Site 3 (8 ± 7 n/l).

Of the recorded taxa, *Tropocyclops* sp. was the most perennial species at all sites with distinctly high density at Site 1 (4-750 n/l). In addition, among the Cladocera *Ceriodaphnia reticulata* (0-99 n/l) in the pond, *Daphniopsis* sp. (0-60 n/l), *Simocephalus serrulatus* (2-12 n/l) and *Alona guttata* (0-12 n/l), in the peat bog and *Pleuroxus similis* (0-11 n/l) and *Alona costata* (1-9 n/l) in the paddy-field were of relatively higher quantitative importance. On the other hand, among the recorded rotifers *Euchlanis dilatata* (0-11 n/l) in the paddy-field exhibited relatively high abundance.

Further, greater impact of abiotic factors on all biotic components was recorded in the pond (Site 1) followed by the peat bog (Site 2) and the least in the paddy-field (Site 3). Of all the recorded abiotic parameters, pH assumed most important role at Site 1 (pond) and it correlated with six communities including directly with phytoplankton and indirectly with net plankton and zooplankton. At Site 2, rainfall positively influenced abundance of six communities including net plankton, phytoplankton, Chlorophyceae, Cyanophyceae, Dinophyceae as well as Rhizopoda. Similarly, transparency correlated inversely with phytoplankton, Chlorophyceae, Cyanophyceae, Dinophyceae as well as Rotifera and Rhizopoda, thereby, indicating the importance of higher light penetration for these communities in the peat bog. On the other hand, in the paddy-field (Site 3), only total hardness registered positive correlations with zooplankton and copepods and inverse with Bacillariophyceae, Euglenophyceae and Ostracoda while water temperature registered positive correlation with only Rotifera and inverse with net plankton, phytoplankton and Cyanophyceae.

On the other hand, multiple regression of net plankton, phytoplankton and zooplankton with twenty abiotic factors viz. water temperature (x_1), rainfall (x_2), transparency (x_3), specific conductivity (x_4), pH (x_5), dissolved oxygen (x_6), free CO₂ (x_7), total alkalinity (x_8), total hardness (x_9), calcium (x_{10}), magnesium (x_{11}), sodium (x_{12}), potassium (x_{13}), chloride (x_{14}), sulphate (x_{15}), phosphate (x_{16}), nitrate (x_{17}), silicate (x_{18})

dissolved organic matter (x_{19}) and total dissolved solids (x_{20}) accounted for 73%, 95% and 85% of variations of net plankton density at Sites 1-3 respectively, while the step-wise regression of ten factors (x_{1-10}) accounted for 56%, 81% and 62% of variations respectively. Similarly, the impact range of the stated ten to twenty abiotic factors on phytoplankton density was 61-92% at Site 1 > 70-84% at Site 3 > 83-95% at Site 2 and zooplankton exhibited Site 3 (58-96%) > Site 1 (79-96%) > Site 2 (74-99%) indicating wider ranges of impact on net plankton and phytoplankton at Site 1 (pond) while on zooplankton at Site 3 (paddy-field). On the other hand, Site 2 (peat bog) depicted maximum cumulative impact of the abiotic factors on all three main planktonic groups, while least impact of abiotic factors was seen in the paddy-field, thereby, indicating the role of other factors including human interventions in this ephemeral ecosystem.

ANOVA indicated significant variations in eight abiotic factors between months as well as between all sites, while 16 out of 20 recorded abiotic parameters exhibited significant variations between the sites. Similarly, Cladocera abundance and the species richness of copepods depicted variations between months as well as the sites, while eight important biotic components viz., phytoplankton, zooplankton, Chlorophyceae, Bacillariophyceae, Euglenophyceae, Rotifera, Copepoda and Rhizopoda exhibited significant variations in their abundance as well as in their species richness between the sites. These findings clearly showed the contrasting ecological characteristics of the three regularly monitored biotopes in eastern Bhutan.

REFERENCES

- Agarwal, D.K., Gaur, S.D., Tiwari, I.C., Narayanswami, N. and Mawrah, S.M. 1976a. Physico-chemical characteristics of Ganges water at Varanasi. *Indian J. Environ. Health*, **18** : 201-206.
- Agbeti, M.D., Kingston, J.C., Smol, J.P. and Watters, C. 1997. Comparison of phytoplankton in two lakes of different mixing regimes. *Arch. Hydrobiol.* **140(1)** : 37-69.
- Akpan, A.W. 1995. Limnology and net plankton periodicity of tropical freshwater pond in Uyo (Nigeria). *Tropical freshwater Biology*, **4** : 65-81.
- Alfred, J.R.B. and Thapa, M.P. 1995. Limnological investigation on Ward's lake- a wetland in Shillong, Meghalaya, N.E. India. *Rec. Zool. Surv. India*, Occ. paper, **169** : 1-125.
- Alikuhni, K.H., Choudhury, H. and Ramachandran, V. 1955. On the mortality of carp fry in nursery ponds and the role of plankton. *Ind.J. Fish.*, **2** : 257-323.
- Ambasht, R.S. 1998. World water and wetland resources. In: *Modern Trends in Ecology and Environment* (ed. R.S. Ambasht). Backhuys Publishers, Leiden, The Netherlands. 115-130.
- Anon, 1992. Bhutan towards sustainable development in a unique environment. National Environment Secretariat, Planning Commission Thimphu. 71 pp.
- Anon, 1998. Biodiversity Action Plan for Bhutan. Ministry of Agriculture, Thimphu, 168 pp.
- Anon, 2002. International Year of Freshwater. Department of Public Information, United Nations.
- Anon, 2003. Water for people water for life, The United Nations World Water Development Report. UNESCO Publishing.
- A.P.H.A. 1992. *Standard Methods for Examination of water and wastewater* (18th Ed.). American water Works Association and Water Pollution Control Federation, New York. 1198 pp. (Eds. Arnold E. Greenberg, Lenore S. Clesceti and Andrew D. Eaton.).
- Arcifa, M.S. Carvalho, M.A. J., Cianesella – Galvao, S.M.F., Shimzu, G.Y., Froelich, C.G. and Castro R.M.C. 1981. Limnology of ten reservoirs in Southern Brazil. *Verh. Internat. Verein. Limnol.*, **21** : 1048-1053.
- Arora, R. K. 1990. Water pollution: studies on nitrite in Kanglung waters. In: *Bhutan and Its Natural resources*, Vikas Publishing House Pvt Ltd., New Delhi.

- Bagla, P. 2002. Melting Himalayan Glaciers May Doom Towns. *National Geographic News*, May 7, 2002, New Delhi.
- Balkhi, M.H., Yousuf, M.Y. and Quadri, M.Y. 1987. Hydrobiology of Anchar lake, Kashmir. *Compo. Physiol. Ecol.* **12** (3) 131-139.
- Barbosa, F.A.R. 1981. *Variacos diurnas (24 horas) de Parametros limnologicos e da Productividae Primaria do fitoplancton na Lagos Carioca-Parque Florestral do Rio Doce-MG-Brasil*. Ph.D. Thesis. Univ. Fed. S. Carlos.
- Battish, S. K. 1992. Freshwater Zooplankton of India. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. 233 pp.
- Berger, W.H. and Parker, F.L. 1970. Diversity of planktonic Foramanifera in deep sea sediments. *Science*, **168** : 1345-1347.
- Bhattacharya, B. 1980. *Biology of Cladocera in an altitudinal lake and ponds in Shillong area*. Ph.D. Thesis. North-Eastern Hill University, Shillong, Meghalaya.
- Bhattacharya, T. and Saha, R.K. 1986. A comparative study of the physico-chemical condition of the water and plankton of Gumti Reservoir, open channel and river below hydel project in Tripura. *Proc. Natl. Symp. Env.*, 61-65 pp.
- Bhattacharya, T. and Saha, R.K. 1990. Limnological studies of the Gumti watershed in Tripura. *Impact of Environment on Animals and Aquaculture*, 183-186.
- Bond, R.M. 1934. Yale North India expedition: report on Phyllopod Crustaceae. *Mem. Conn. Acad. Arts et Sci.*, **10** : 29-62.
- Brehm, V. 1936. Yale North India expedition. Report on Cladocera. Article XVI. *Mem. Conn. Acad. Arts et Sci.*, **10** : 283-297.
- Chacko, P.I. and Krishnamurthy, B. 1954. On the plankton of freshwater fish ponds in Madras city, India. *Proc. Indo-Pacific Fisc Counc., Sect II.*, **5** : 103-197.
- Chandler, D.C. 1942. Limnological studies of western lake Erie. III. Phytoplankton and physical chemical data from November 1939 to 1940. *Ohio J. Sci.*, **42** : 24-44.
- Chowdhary, S.K., Sharma J.P. and Srivastava, J.B. 1988. Limnological Studies of Jammu Ponds. In: *Recent Advances in Fish Ecology Limnology and Eco-conservation* (Ed. Surendra Nath). Creative Publishers, New Delhi. 73-78.
- Clarke, G.L. 1954. *Elements of Ecology*. Wiley International, 560 pp.
- Clement, P. 1980. Phylogenetic relationships of rotifers as derived from photoreceptor morphology and other structural analyses. *Hydrobiologia*, **73** : 93-117.

- Cole, G.A. 1957. Studies on Kentucky Knobs Lake. III. Some qualitative aspects of the net plankton. *Trans. Kentucky Acad. Sci.* **18** : 88-101.
- Daems, G. and Dumont, H.J. 1974. Rotifers from Nepal with description of a new species of *Scaridium* and a discussion of the Nepalese representatives of the genus *Hexarthra*. *Biol. Jb. Dodonaea*, **42** : 61-81.
- Das, P. K. Michael, R.G. and Gupta, A. 1996. Zooplankton community structure in lake Tasek, a tectonic lake in Garo Hills, India. *Tropical Ecology*, **39**: 257-263.
- Das, S. M. (1974). Teaching, Training and Research in high altitude limnology in Kumaon – Garhwal University. *Uttarkhand Bharati* 1(1-2), Kumaon University, Nainital, 82-85pp.
- Das, S.M. (1976), Rotifers of Kashmir. *Rotifer News*, **2**: 12-16.
- Das, S.M. (1978a). High pollution in Lake Nainital as evidenced by biological indicators. *Sci & Cult*, **44(5)** : 236-237.
- Das, S.M. and Akhtar, S. (1970). Ecology of Dal Lake, Kashmir. *Polish Symposium on Limnology*, IBP Report, Cracow, Poland: 24-32.
- Das, S.M. and Akhtar (1971). Ecology of High altitude Lakes of Kashmir. *Ichthyologica*, **10(1-2)** : 6-12.
- Das, S.M. and Akhtar, S. (1973). High altitude fish ecology and Fish Production. *IUCN Report*: 18-23.
- Das, S.M. and Akhtar, S. (1984). The biological production of some temperate wetland lake ecosystems of Kashmir: The plankton, pedon and fish. P.55-78, In: S.C. Joshi, D.R. Joshi and D.D. Dani (eds.) *Rural development in the Himalaya*. Gyanodaya Prakashan, Nainital., U.P.
- Das, S.M. and J. Pande (1978 b). Lake Pollution as evidenced by Physical, Biological and Chemical Parameters. *Proc. Nat. Sem. On Res. And Dev. In the Himalayan Region*, New Delhi: 502-512.
- Das, S.M. and J.C. Upadhyaya (1979). Studies on Qualitative and Quantitative Fluctuations of Plankton in two Lakes, Nainital and Bhimtal, India, *Act. Hydrobiol.*, **21(1)** : 9-17.
- Datta, N.C. 2001. Biomonitoring of aquatic environment-concept, scope and limitations. In: *Water Quality Assessment, Biomonitoring and Zooplankton Diversity* (Ed. B.K. Sharma) 36-44. Department of Zoology, NEHU, Shillong.
- Dhendup, T. and Boyd, C. E. 1994. Chemical features of water and soil farming areas in Bhutan. *J. Aqua. Trop.*, **9** : 35-41.

- Dumont, H. J. and Van de Velde I. 1977. Report on a collection of Cladocera and Copepoda from Nepal. *Hydrobiologia*, **53**, I : 55-65.
- Dumont, H.J. 1983. Biogeography of rotifers. *Hydrobiologia*, **104** : 19-30.
- Edmondson, W.T. 1959. *Freshwater Biology*. 2nd Edn. John Wiley and Sons. Inc. New York. 1248 pp.
- Edmonson, W.T., Hutchinson. 1934. Report on Rotatoria of Yale North India expedition. *Mem. Conn. Acad. Arts et Sci.* **10** : 153-156.
- Eilers, J.M., Brakke, D.F., Landers, D.H. and Keller, P.E. 1988. Characteristics of lakes in mountain areas of the western United States. *Verh. Internat. Verein. Limnol.*, **23** : 144-151.
- Fernando, C.H. 1993a A bibliography of references to rice field aquatic fauna, their ecology and rice-fish culture. SUNY Genesco-Univ, Waterloo, Genesco N.Y., V and pp 110.
- Fernando, C.H. 1995. Rice fields are aquatic, semi-aquatic, terrestrial and agricultural: A complex and questionable limnology. In: Tropical Limnology. Vol. I: 121-148. (Eds. K.H. Timotius and F. Goltenboth). Satya Wacana Christian University, Salatiga, Indonesia.
- Forbes, S.A. 1887. "The Lake as a Microcosm." Bull. Peoria (Illinois) Sci. Assoc. Reprinted 1925 in *Bull Ill. Nat. Hist. Surv*, **15** : 537-550.
- Forel, F.A. 1901. *Handbuch der Seenkunde: allegemeine Limnologie*. Biiothek geographische Handbbücher, Stuttgart.
- George, M.G. 1961. Observation on the rotifers from shallow ponds in Delhi. *Curr. Sci.*, **30** : 265-269.
- Goel, P.K., Kulkarni, A.Y. and Khatvkar, S.D. 1988. Species diversity in phytoplankton communities in a freshwater body in Southern Maharastra. *Geobios*, **15(4)**: 150-156.
- Gopal, B., Goel, P.K., Sharma, K.P. and Trivedi, R.K. 1981. Limnological study of a freshwater reservoir, Jamwa Ramgarh (Jaipur). *Hydrobiologia*, **83**: 283-294.
- Grimshaw, H.M. and Hudson, M.J. 1970. Some mineral nutrient studies of a low land mere in Chesire, England. *Hydrobiologia*, **36**: 329-341.
- Gyeltshen, T. 2001. Bhutan Water Partnership launched. In: *Kuensel, Bhutan's National Newspaper*. Vol.XVI. No.34.

- Hanazato, T. (1999). Global Environment and Lake Ecosystems. In: *Limnology- The Textbook for the ninth IHP Training Course in 1999* (Ed. Hisayoshi Terai), Institute for Hydrospheric –Atmospheric Sciences, Nagoya University and UNESCO. 241 pp.
- Heckman, C.W. 1979. *Rice field ecology in North-Eastern Thailand*. Dr. W. Junk Publishers, The Hague, 228 pp.
- Hickel, B. 1973a. Limnological Investigation in Lakes of Pokhara valley, Nepal. *Int. Rev. ges. Hydrobiol.* **58**: 659-672.
- Hickel, B. 1973b. Phytoplankton in two ponds (Tau Daha and Nag Daha) in Kathmandu valley, Nepal. *Int. Rev. ges. Hydrobiol.* **58**: 835-842.
- Horne, Alexander J. and Goldman, Charles R. 1994. *Limnology* (2nd ed). McGraw-Hill Inc., New York. 576 pp.
- Hutchinson, G.E., 1937. Limnological studies in Indian Tibet. *Int. Rev. Hydrobiol.*, **35** : 134-177.
- Hutchinson, G.E., 1957a. *A Treatise on Limnology Vol. I Geography, Physics and Chemistry*. John Wiley and Sons Inc. New York, USA.1015 pp.
- Hutchinson, G.E., 1957b. Concluding remarks on Yale North India expedition. *Cold Spring Harbour Symposium, Quant. Biol.* **22** : 527.
- Hutchinson, G.E., 1967. *A Treatise on Limnology II: Introduction of lake biology and limnoplankton*, John Wiley and sons Inc., New York. 115 pp.
- Hutchinson, G.E., Pickford, G.E. and Schurmann. 1932. A contribution of Hydrobiology of Pus and other inland waters of South Africa. *Arch. Hydrobiol. Suppl. B.* **24** : 1-54.
- Jain, A, Rai, S.C., Pal, J. and Sharma, E. 1999. Hydrology and nutrient dynamics of a sacred lake of Sikkim Himalaya. *Hydrobiologia*, **416**: 13-22.
- Jain, A, Rai, S.C. and Sharma, E. 2000. Hydro-ecological analysis of a sacred lake watershed system in relation to land-use/cover change from Sikkim Himalaya. *Catena*, **40**: 263-278.
- Jhingran, V.G. 1982. *Fish and Fisheries of India*. 2nd ed. Hindustan Publishing Corporation, India.
- Jhingran, V.G. 1991. *Fish and fisheries of India*. Hindustan Publishing Corporation (India), Delhi, (3rd edition). 727 pp.

- Jyrwa, M. 1996. *Investigations on temporal changes in water quality and plankton ecology in a rice-field ecosystem in Jaintia hills district (Meghalaya)*. M.Phil thesis. North Eastern Hill University, Shillong, Meghalaya.
- Kalff, J. 2002. *Limnology: Inland Water Ecosystems*. Prentice Hall Upper Saddle River, New Jersey. 592 pp.
- Kant, S. and Kachroo. 1974. Limnological studies in Kashmir lakes. IV. Seasonal dynamics of phytoplankton in the Dal and Nagin. *Proc. Indian Natn. Sci. Acad.* **40B** : 77-99.
- Kaul, S. (1982). Community Structure, Biomass and Production in some typical wetlands of Kashmir, India. *Indian J. Ecol.*, **9(2)** : 320-329.
- Kaul, V. 1977. Limnological survey of Kashmir lakes with reference to trophic status and conservation. *Int. J. Ecol. Environ. Sci.* **3** : 29-44.
- Kaul, V. 1988. The Interdisciplinary approach to save the dying Dal Lake in Kashmir. In: *Recent Advances in Fish ecology, Limnology and Eco-conservation* (Ed. Surendra Nath). Creative Publishers, New Delhi. 176 pp.
- Kaul, V., Fotedar, D.N., Pandita, A.K. and Trisal, C.L. 1978. A comparative study of plankton populations of some typical freshwater bodies of Jammu and Kashmir. *Environ. Physiol. Ecol. Plants* : 249-269.
- Kaul, V. and Zutshi, D.P. 1971. Ecological problems of Kashmir lakes.. In: Misra, R. and R.R. Das (eds.). *Proc. School of ecology*, Varanasi. 257-270.
- Kaul, V. and Handoo, J.K. 1987. Chemical parameters useful in the evaluation of eutrophication and ecological state of lakes of Jammu and Kashmir. In: S.K. Agarwal and R.K. Garg (eds.) *Environmental Issues and Researches in India*. Himanshu Publication, Udaipur. 363-397.
- Kaul, V. and Handoo, J.K. 1989. Studies on the Ecology of Kashmir Himalaya. In: *Perspectives in Ecology* (Eds. J.S. Singh and B. Gopal). Jagminder Book Agency, New Delhi. 1-48.
- Kaul, V. and Pandita, A.K. 1981. Benthic communities as indicators of pollution with reference to wetland ecosystems of Kashmir. In: *Biological Indicators and Indices of Environmental Pollution*. Proc. WHO Workshop. Cent. Bd. Prev. Cont. Water Poll., Osmania Univ., Hyderabad, 33-52 pp.
- Kaul, V. and Pandit, A.K. 1982. Biotic factors and food chain structure in some typical wetlands of Kashmir. *Poll. Res.*, **1 (1-2)** : 45-54.
- Kaushik, S and Sharma, N. 1994. Physico-chemical characteristics of zooplankton populations of a perennial tank, Matsya Sarovar, Gwalior. *J. Environ. Ecol.*, **12** : 429-434.

- Kaushik, S. and Saksena, D.N. 1999. Physico-chemical Limnology of certain water bodies of central India. In: *Freshwater Ecosystems of India*. (Ed. K. Vijayakumar), Daya Publishing House, Delhi. 2-58.
- Kelly, M.H., Fitzpatric, L.C. and Pearson, W.D. 1978. Phytoplankton dynamics, primary productivity and community metabolism in north central Texas Pond. *Hydrobiologia*, **50(2)** : 177-189.
- Khan, M.A. and Zutshi, D.P. 1980b. Contribution to high altitude limnology of the Himalayan system 1. Limnology and primary productivity of the plankton community of Nilnag Lake, Kashmir. *Hydrobiologia*, **75**: 103-1112.
- Koste, W. 1978. *ROTATORIA*. Die Radertiere Mitteleuropas, begründet von Max Voigt. Überordnung Monogononta. Gebrüder Borntraeger, Berlin, Stuttgart. I. Text. (673 pp) U. II Tafelbd. (T. 234).
- Kundangar, M.R. and Zutshi, D.P. 1985. Environmental features and plankton communities of two Himalayan rural lakes. In: A.D. Adoni (ed.) *Proc. Nat. Symp. Pure and Appl. Limnology. Bull. Bot. Soc. Sagar*. **32** : 40-47.
- Kutikova, L.A. 1970. The Rotifer fauna of the USSR - Fauna USSR 104, *Academia Nauk*, 744 pp (in Russian).
- Lakiang, M. 1998. *Composition and ecology of plankton in Thadlaskein Lake (Meghalaya)*. M.Phil. Thesis. North-Eastern Hill University, Shillong, Meghalaya.
- Lauterborn, R. 1893. Beiträge zur Rotatirienfauna des Rheins und seiner Altwässer. *Zool. Jahrb. Abt. Syst.*, **7**: 254-273.
- Lewis, W.M. and Weibezahn, F.H. 1976. Chemistry energy flow and community structure in some Venezualan freshwater. *Arch. Hydrobiol. Suppl.*, **50**: 145-207.
- Löffler, H. 1969. High altitude lakes in Mt. Everest region. *Verh. Internat. Verein. Limnol.* **17**: 373-385.
- Ludwig, J. A. and Reynolds, J.F. 1988. *Statistical ecology: a primer on methods and computing*. John Wiley & Sons, New York. 337 pp.
- Lyngdoh, J. 1998. *Species composition and ecology of zooplankton in a sub-tropical lentic ecosystem of Meghalaya*. M.Phil. Thesis. North Eastern Hill University, Shillong Meghalaya.
- Lyngdoh, R.M. 2002. *Biodiversity and Synecology of plankton in a sub-tropical reservoir of Meghalaya*, Ph.D Thesis. North Eastern Hill University, Shillong Meghalaya.

- Magurran, A. E. 1988. *Ecological Diversity and its measurement*. Croom Helm Limited, London. 179 pp.
- Maharana, I., Rai, S.C. & Sharma, E. 2000. Valuing eco-tourism in a sacred lake of the Sikkim Himalaya, India. *Environmental Conservation*, **27(3)** : 269-277.
- Malthus, T.J. and Mitchell, S.F. 1988. Agricultural development and eutrophication of Lake Mahinerangi, New Zealand. *Verh. Internat. Verein. Limnol.*, **23**: 1028-1031.
- Malthus, T.J. and Mitchell, S.F. 1990. On the occurrence, causes and potential consequence of low zooplankton to phytoplankton ratios in New Zealand lakes. *Freshwater Biology*, **22** : 383-394.
- Margalef, R. 1964. Correspondence between the classical types of tables and the structural and dynamic properties of their population. *Verh. Internat. Verein. Limnol.* **15** : 169-175.
- Margalef, R. 1968. *Perspectives in Ecological Theory*. Univ. Chicago. Press, Chicago. 111 pp.
- Mathew, P.M. 1975. Limnology and productivity of Govindgarh lake, Rewa, Madhya Pradesh. *J. Inland Fish.Soci. India*, **7**: 16-24.
- Mc Naughton, J. 1967. Relationship among functional properties of California grassland. *Nature*, **216** : 168-169.
- Menhinick, E.P. 1964. A comparison of some species-individuals diversity indices applied to samples of field insects. *Ecology*, **45**: 859-861.
- Michael, R.G. and Sharma, B. K. 1988. INDIAN CLADOCERA. (Crustacea: Branchiopoda: Cladocera). *Fauna of India and adjacent countries*. Zool. Surv. India, Calcutta. 262 pp.
- Mishra, G.P. and Yadava, A.K. 1978. A comparative study of physico-chemical characteristic of river and lake water in central India. *Hydrobiologia*, **59** : 275-278.
- Moss, B. 1988. *Ecology of Freshwaters Man and Medium* (2nd edition). Oxford Blackwell Scientific Publications, London. 417 pp.
- Moyle, J.B. 1946. Some indices of lake productivity. *J. Amer. Fish. Soc.*, **76** : 322-324.
- Müller, P.E. 1867. Denmark Cladocera. *Schiödtes. Naturhist. Tidskr.*, **3**: 53-240.
- Myers, F.J. 1934. The distribution of rotifera on Mount Desert Island. Part VI. New Brachionidae of the genus *Lepadella*. *Amer. Mus. Novitates*, **760** : 1-10.

- Nasar, S.A.K. 1977. Diurnal variations in physico-chemical factors in a pond in Bhagalpur, India. *Comp. Physiol. Ecol.*, **2**:145-149.
- Negi, V. and Pant, M.C. 1983. Analysis of Zooplankton Community of Laka Khurpatal (Kumaon Himalaya). *Tropical Ecology*, **24**: 271-282.
- Nielsen, S. E. 1952. The use of radioactive carbon (^{14}C) for measuring organic production in the sea. *J. Cons. Int. Expl. Mer* **18** : 117-140.
- Nongtraw, I. 1998. *Composition and ecology of plankton in some freshwater ponds in Meghalaya*. M.Phil. Thesis. North-Eastern Hill University, Shillong, Meghalaya.
- Ohle, W. 1934. Chemische und Physikalische Untersuchungen noddutcher seen. *Arch. Hydrobiol.*, **26** : 386-464.
- Ohle, W. 1938. Die Bedeutung der Anstanschl Vorgange Zwischen Schalamn und wasser fur der Gewasser, "Vom Wasser".
- Pandit, A.K. 1999. Trophic Structure of Plankton Community in some Typical Wetlands of Kashmir, India. In: *Limnological Research in India* (Ed. S.R. Mishra), Daya Publishing House, Delhi. 190-224.
- Pandit, A.K. Kaul, V., 1982. Trophic structure of some wetlands. In: B. Gopal, R.E. Turner: R.G. Wetzel and D.F. Whigam (eds.) *Wetlands : Ecology and Management*. NIE and Int. Publ., Jaipur, 55-83.
- Parsons, T.R. 1980. Zooplankton Production. In: *Fundamentals of Aquatic Ecosystems* (Ed. R.S. Barnes and K.H. Mann), Blackwell Scientific Publications. 46-66.
- Patil, C.S. and Gouder, B.Y.M. 1985. Ecological study of freshwater zooplankton of a sub-tropical pond (Karnataka State, India). *Int. Revue ges. Hydrobiol.*, **70** : 259-267.
- Patil, H.S. and Karikal, S.M. 2001. Zooplankton diversity of Bhutnal water reservoir at Bijapur-Karnataka state. In: *Water Quality Assessment, Biomonitoring and Zooplankton diversity* (Ed. B.K. Sharma) pp 236-243. Department of Zoology, North-Eastern Hill University, Shillong.
- Payne, A.R. 1986. *The ecology of tropical lakes and rivers*. John Wiley & Sons. New York. 301 pp.
- Pejler, B. 1977. On the global distribution of family Brachionidae (Rotatoria). *Arch. Hydrobiol. Suppl.*, **53** : 225-306.
- Phillopose, M.T. 1960. Freshwater phytoplankton of inland fisheries. *Proc.Symp. Algology*, ICAR, New Delhi : 272-291.
- Pielou, E.C. 1975. *Ecological Diversity*. J. Wiley, New York, 165 pp.

- Pont, D. (1977). Structure at evolution saisonniere de populations de copepods, cladoceres et ostracodes des rizieres de Camargue. *Ann. Limnol.*, 13: 15-28.
- Prakash, S. 2001. Seasonal dynamics of plankton in a freshwater water body at Balrampur. *Geobios*, 28: 29-32.
- Quadri, M.Y. and Yousuf, A.R. 1978. Seasonal variations in the physico-chemical factors of sub-tropical lake of Kashmir. *J. Inland. Fish. Soc. India*, 10: 89-96.
- Quadri, M.Y. and Yousuf, A.R. 1988. A comparative study of the Limnology of three typical water bodies of Kashmir. In: *Recent Advances in Fish Ecology Limnology and Eco-conservation* (Ed. Surendra Nath). Creative Publishers, New Delhi, 176 pp.
- Ravichandran, S. and Ramanibai, P.S. 1988. The physical and chemical limnology of Buckingham canal (Madras, India). *Arch. Hydrobiol.*, 114(1) : 97-115.
- Ray, P.S., Singh, S.P. and Sehgal, K.L.A. 1966. A study of some aspects of the rivers Ganga and Yamuna at Allahbad (U.P.) in 1958-1959. *Proc. Nat.Acad. Sci. India*, 36(B) : 235-272.
- Ruttner, F., 1953. *Fundamentals of Limnology* (1st ed.). Toronto Univ. Press, Toronto, 295 pp.
- Saha, G.N., Sehegal, K.L., Mitra, E. and Nanda, A.C. 1971. Studies on the seasonal and diurnal variations in physico-chemical and biological conditions of a perennial freshwater pond. *J. Inland Fish. Soc. India*, 3 : 79-102.
- Saeger, P.E. and Hasler, A.D. 1969. Species –diversity in lacustrine phytoplankton. I. The components of the index of diversity from Shannon's formula. *Am. Nat.* 130 : 51-59.
- Sarwar, S.G. 1999. Water Quality and Periphytic Algal Component of Anchar Lake in Kashmir. In: *Freshwater Ecosystem of India* (ed. K. Vijayakumar). Daya Publishing House, Delhi. 237-250 pp.
- Sawyer, C.H. 1960. *Chemistry for Sanitary Engineers*. Mc Graw Hill Book Co., New York.
- Schanz, F. 1984. Chemical and algological characteristics of five high mountain lakes near Swiss National Park. *Verh. Internal. Verein. Limnol.*, 22: 1066-1070.
- Seenayya, G. 1971. Ecological studies in the plankton of certain freshwater ponds of Hyderabad (India). II Phytoplankton. *Hydrobiologia*, 37: 55-88.

- Segers, H. 1995. *Rotifera 2: Lecanidae. Guides to Identification of the Microinvertebrates of the Continental waters of the World.* 6: 1-226 (Eds. H.J. Dumont and T. Nogrady). SPB Academic Publishing bv. Amsterdam, The Netherlands.
- Segers, H. 1996. The biogeography of littoral *Lecane* Rotifera. *Hydrobiologia*, **323** : 169-196.
- Segers, H. 2001. Zoogeography of the South East Asian Rotifera. *Hydrobiologia*, **446/447** : 233-246.
- Sharma, B.K. 1983. The rotifer community of Mondsee, an alpine lake in Austria. I. Species diversity and community structure. II. Ecology of Planktonic Rotifera. Institute of Limnology, Austrian Academy of Sciences, Mondsee, Austria. 80 pp.
- Sharma, B.K. 1995. Limnological studies in a small reservoir in Meghalaya (N.E. India). In: *Tropical Limnology*, Vol II: 187-197. (Eds.) Timotius K.H. and Goltenboth F. Satya Wacana Christian University Press, Salatiga, Indonesia.
- Sharma, B.K. 1999. Water Quality of three sub-tropical reservoirs of Meghalaya. *Proc. Nat. Symp. Pollution Man and Env.* Shillong: 127-133.
- Sharma, B.K. 2001a. Water Quality of Subtropical lentic biotopes of Meghalaya. In: *Water Quality Assessment, Biomonitoring and Zooplankton Diversity.* (Ed. Prof. B.K Sharma), Department of Zoology, North Eastern Hill University, Shillong, Meghalaya. 10-22 pp.
- Sharma, B.K. 2001b. Biological monitoring of freshwaters with reference to role of freshwater Rotifera as biomonitors. In: *Water Quality Assessment, Biomonitoring and Zooplankton Diversity.* (Ed. Prof. B.K Sharma), Department of Zoology, North Eastern Hill University, Shillong, Meghalaya. 83-97 pp.
- Sharma, B.K. 2001c. Zooplankton Diversity: Freshwater Planktonic and Semi-Planktonic Rotifera. In: *Water Quality Assessment, Biomonitoring and Zooplankton Diversity.* (Ed. Prof. B.K Sharma), Department of Zoology, North Eastern Hill University, Shillong, Meghalaya. 190-210 pp.
- Sharma, B.K. 2001d. Zooplankton Diversity: Freshwater Planktonic Cladocera (Crustacea: Branchiopoda). In: *Water Quality Assessment, Biomonitoring and Zooplankton Diversity.* (Ed. Prof. B.K Sharma), Department of Zoology, North Eastern Hill University, Shillong, Meghalaya. 215-235 pp.
- Sharma, B.K. and Hussain, Md. 1999. Temporal variations in abiotic factors of a tropical floodplain lake, Upper Assam (N.E. India). *Rec. Zool. Surv. India*, **97**: 145-150.
- Sharma, B.K. and Lyngdoh, R.M. 1999. Limnological studies in Umiam Reservoir, Meghalaya. *Proc. National Symposium in Trends in Environmental Biology*, North Eastern Hill University, Shillong.

- Sharma, B.K. Lyngdoh, R.M. 1999. Temporal and horizontal variations in abiotic parameters in Umiam reservoir (Meghalaya). *Proc. Nat. Conf. Pollution Man & environment, Shillong*: 17-23.
- Sharma, B.K. and Lyngdoh, R.M. 2003. Abundance and ecology of net plankton and phytoplankton of sub-tropical reservoir of Meghalaya (N.E. India). *Eco. Env. & Cons.* **9 (4)** : 485-491.
- Sharma, B.K. and Lyngdoh, R.M. 2004. Zooplankton communities of Umiam reservoir, Meghalaya (N.E. India): Composition, abundance and ecology. *The Indian Journal of Animal Science* (in press).
- Sharma, B.K. and Lyngskor, C. 2003. Planktonic communities of a sub-tropical reservoir of Meghalaya (N.E. India). *Indian J. Animal Sci.* **73(2)** : 88-95.
- Sharma, B.K. and Sharma, Sumita. 1987. On species of the genus *Lepadella* (Eurotatoria: Monogononta: Colurellidae) from north-east India, with remarks on Indian taxa. *Hydrobiologia*, **147**: 15-22.
- Sharma, B.K. and Sharma, Sumita. 1990. On the distribution of brachionid rotifers (Eurotatoria: Brachionidae) in North Eastern India. In: *Current Trends in Environmental Biology* (Eds. R.R. Mishra and K. Chatterjee). Wiley Eastern Limited: 189-196.
- Sharma, B.K. and Sharma, Sumita, 1997. Lecanid rotifers (Rotifera: Monogononta: Lecanidae) of North Eastern India. *Hydrobiologia*, **356**: 159-163.
- Sharma, B.K. and Sharma, Sumita. 1999a. Freshwater Rotifers (Rotifera: Eurotatoria). In *Fauna of Meghalaya. State Fauna Series*, **4(9)** : 11-161. Zool. Surv. India, Calcutta.
- Sharma, B.K. and Sharma, Sumita. 1999b. Freshwater Cladocerans (Crustacea: Branchiopod: Cladocera). In *Fauna of Meghalaya. State Fauna Series*, **4(9)** : 469-550. Zool. Surv. India, Calcutta.
- Sharma, B.K. and Wanswett, D. 1999. Abiotic environment of a lentic ecosystem of Cherrapunjee (East Khasi Hill District), Meghalaya. *Proc. Nat. Conf. Pollution Man & environment, Shillong*: 7-11.
- Sharma, P.C. and Pant, M.C. 1985. Species composition of zooplankton in two Kumaon Himalayan lakes (U.P. India). *Arch. Hydrobiol.*, **102**: 387-403.
- Shukla, S.C., Kant, R. and Tripathi, B.D. 1989. ecological investigation on physico-chemical characteristics and phytoplankton productivity of river Ganga at Varanasi. *Geobios*, **16** : 20-27.

- Sikandar, M. and Tripathi, B.D. 1984. The physico-chemical characteristic of Ganga water at Varanasi. In: *River Ecology and Human Health*. (eds. R.S. Ambasht and B.D. Tripathi). *National Env. Conser. Assoc.*, 53-61.pp.
- Singh, D.N. 2000. Seasonal variation of Zooplankton in a Tropical Lake. *Geobios*, **27(2-3)**, 97-100.
- Singh, S.P., Pant, M.C., Sharma, P.C. and Purohit Rekha. 1982. Limnology of Shallow Water zones of lakes in Kumaon Himalaya (India). In: *Proc. First International Wetlands Conference* (Eds. B. Gopal, R.K. Turner, R.G. Wetzel and D.F. Whigham), Jaipur, India. 39-49.
- Sinha, A.K. Baruah, A., Singh, D.K. and Sharma, U.P. 1994. Biodiversity and pollution in relation to physico-chemical factors of Kawar lake (Begusarai), North Bihar. *J. Freshwater Biol.*, **6** : 309-331.
- Sladeczek, V. 1983. Rotifers as indicators of water quality. *Hydrobiologia*, **100** : 169-201.
- Smirnov, N.N. 1971. The World Chydorid Fauna (in Russian). *USSR Acad. Sci. Zool. Inst. Nova. Ser. No 101*. Leningrad. 539 pp.
- Smirnov, N.N. 1976. World Macrothricidae and Moinidae (in Russian). *USSR Acad. Sci. Zool. Inst. Nova. Ser. No. 112*. Leningrad. 237 pp.
- Sondergaard, M. and Sand-Jensen, K. 1979. Physio-chemical environment, phytoplankton biomass and production in oligotrophic soft water lake, Kalgaard, Denmark. *Hydrobiologia*, **63**: 241-253.
- Sorensen, T. 1948. A method of establishing group of equal amplitude in plant sociology based on similarity of species content and its application to analysis of the vegetation of Danish commons. *Biol. Skr. 5* : 11-34.
- Stewart, K. M. and Karkello, S.J. 1974. Seasonal variations in concentration of nitrate and total phosphorous and calculated nutrient loading for six lakes in western New York. *Hydrobiologia*, **44 (1)** : 61-89.
- Strom, K.M. 1921. The phytoplankton of some Norwegian lakes. *Vidensk. Selekt. Christaina Skr. I. Matnatyry K.I.*, **4** : 1-51.
- Subla, B.A. Zutshi, D.P., Khan, M.A., Vishan, N., Wangaeneo and Raina, R. 1984. Distribution and ecology of zooplankton communities from Kashmir. *Bull. Env.*, **7(1)** : 30-35.
- Sudzuki, M. 1989. Rotifera from the oriental region and their characteristics. *Special Issue Cent. Ann. Nihon Daigaku*, **3** : 301-343.

- Swar, D.B. & Fernando, C.H. 1979. Cladocera from Pokhara valley, Nepal with notes on distribution. *Hydrobiologia* **66** :113-128.
- Swar, D.B. & Fernando, C.H. 1980. Some studies on the ecology of limnetic crustacean zooplankton in Lakes Begnas and Rupa, Pokhara valley, Nepal. *Hydrobiologia* **70** : 235-245.
- Swingle, H.S. 1946a. Standardization of chemical analysis for waters and pond muds. *FAO Fish. Rep.* **44** : 397-421.
- Talling, J.F. and Talling, I.B. 1965. The chemical composition of African lake waters. *Int.Revue ges Hydrobiol.*, **50** : 421-463.
- Tassigny, M. 1971. Action du calcium sur la croissance de Desmidiées axéniques. *Mittl. Intern. Verein. Limnol.*, **19** : 292-313.
- Tsirtsis, G. and Karydis, M. 1998. Evaluation of phytoplankton community indices for detecting eutrophic trends in the marine environment. *Environmental monitoring and Assessment*, **50** : 255-269.
- Ueno, M. 1966. Cladocera and Copepoda from Nepal. *Jap.J. Zool.*, **26** : 95-100.
- Vass, K.K. 1980. On trophic status and conservation of Kashmir lakes. *Hydrobiologia*, **68(1)** : 9-15.
- Vass, K.K., Wanganeo, A., Raina, H.S., Zutshi, D.P. and Wanganeo, R. 1989. Summer limnology and fisheries of high mountain lakes of Kashmir Himalayas. *Arc. Hydrobiol.*, **114** : 603-619.
- Venkateswarlu, V. 1983. Taxonomy and ecology of algae in the river Moosi, Hyderabad, India. II. Bacillariophyceae. *Bibliotheca Phycologica* (Ed. J. Cramer). **66** : 1-44.
- Vyas, L.N., Shankla, S.K., Pliwal, P.P. 1988. Hydrobiological studies of Udaipur Lakes. In: *Perspectives in Ecology* (Eds. J.S. Singh and B. Gopal). Jagminder Book Agency, New Delhi. 389-410.
- Wanswett, D. 2001. *Biodiversity and synecology of plankton in some lentic ecosystems of Cheerapunjee, Meghalaya*, Ph.D Thesis. North Eastern Hill University, Shillong, Meghalaya.
- Wade, W. 1957. Studies on the distribution of desmids in Michigan. *Trans. Amer. Micros. Soc.*, **76** : 80-86.
- Washington, H.G. 1984. Diversity, biotic and similarity indices. A review with special relevance to aquatic ecosystems. *Water Research*, **18** : 653-694.

- Webber, W.J.Jr. and Stumm. 1963. Mechanism of hydrogen ion buffering in natural waters. *J. Amer. Wat. Works Assoc.*, **155** : 1553.
- Welch. P.S. 1952. *Limnology*. 2nd edn. Mc Graw Hill Publication, 538 pp.
- Wetzel, R.G. 1975. *Primary production river ecology*. Blackwell Scientific Publication, Oxford.
- Wetzel, R.G. 1983. *Limnology*. W.B. Saunders, Philadelphia, 767 pp.
- White, E. 1983. Lake Eutrophication in New Zealand, a comparison with other countries of the organization for economic cooperation and development. *New Zealand J. Marine and Freshwater Res.*, **17** : 437-444.
- Woelkerling, W. and Gough, S.B. 1976. Wisconsin Desmids. III. Desmid community composition and distribution in relation to lake type and water chemistry. *Hydrobiologia*, **51** : 3-32.
- Yadava, Y. S., Singh, R.K. Chaudhary, M. and Kolekar, V. 1987. Limnology and productivity in Dighlai beel (Assam). *Tropical Ecology*, **28** : 137-146.
- Yousuf, A. R., Quadri, M.Y., Shah, G.M. and Naqash, S.A. 1983. Crustaceans communities of freshwaters of Kashmir. *J. Indian Inst. Sci.* **64** : 83-89.
- Yousuf, A. R., Quadri, M.Y. 1985. Seasonal fluctuations in zooplankton in lake Manasbal. *Indian J. Ecol.*, **12** (2): 354-359.
- Zachariah, P. 1992. *Limnological studies in a sub-tropical man-made reservoir in Meghalaya state*. M.Phil. Thesis, North-Eastern Hill University, Shillong, Meghalaya.
- Zutshi, D.P. 1981. Evaluation of eutrophication in freshwater lakes using phytoplankton and primary production as indicator. *WHO Workshop on Biological indicators and indices of Environmental Pollution*. Osmania University, Hyderabad, India: 85-91.
- Zutshi, D.P. 1989. 25 years of Ecological Research on Lakes of North-western Himalaya. In: *Perspectives in Ecology* (Eds. J.S. Singh and B. Gopal). Jagminder Book Agency, New Delhi. 510 pp.
- Zutshi, D.P. and Vass K.K. 1970. High Altitude Lakes of Kashmir. *Ichthyologica* **10(1-2)** : 12-15.
- Zutshi, D.P., Subla, B.A. and Khan, M.A. 1980. Comparative limnology of nine lakes of Jammu and Kashmir Himalayas. *Hydrobiologia*, **72** : 101-112.
- Zutshi, D.P. and Vass, K.K. 1978. Limnological studies on Dal Lake: Srinagar. III. Biological features. *Proic. Indian Natn. Sci. Acad. B*, **48(2)** : 234-241.

Zutshi, D.P. and Vass, K.K. 1982. Limnological studies on Dal Lake: Chemical features. *Indian J. Ecol.*, **5** : 90-97.

Zutshi, D.P. and Wanganeo, A. 1984. The phytoplankton and primary productivity of a high altitude sub-tropical lake. *Verh. Int. Verein. Limnol.*, **22** : 1168-1172.

Bio-data

Shiva Raj Bhattarai was born and brought up in a remote village of Myona under Samchi district in Bhutan. He started his education in Sanskrit *Pathsala* but was soon shifted to Denchukha Primary School for modern schooling, continued till fifth standard at Dorokha and completed high school education at Samchi Central School. He did his pre-University as well as first degree at Sherubtse College, Kanglung where he was awarded gold medal for excellence in character, academics and activities. He did his post-graduation in Bioscience in 1991 from Maharshi Dayanand University, Rohtak, India, and since is teaching Zoology at Sherubtse College, Kanglung Bhutan. He is presently the Head and senior lecturer in the department. He has attended several national and international workshops and seminars during the above service period.