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**RECORDS OF THE
ZOOLOGICAL SURVEY OF INDIA**

**Phytofaunal community of two freshwater
lakes of West Bengal, India**

**SUJIT PAL
N. C. NANDI**

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PREFACE

Lakes though occupy a small portion of water available in the world, constitute one of the most important components of freshwater ecosystem. They provide an indispensable natural resource crucial for survival of all living beings including humans. Largely for this reason lake ecology has been the focus of environmental study all over the world. They exhibit enormous diversity based on the genesis, geographical location, hydrological regimes and biotic resources. Freshwater lakes in India as well as in West Bengal are not exceptions to these situations that offer diversified features in water quality, weed infestation, lake use pattern and bio-aesthetic values.

Keeping in view of these hydrobiological and ecological diversities, an attempt has been made to study the macrofaunal community associated with macrophytes of two urban lake ecosystems *viz.*, Rabindra Sarovar (RS) and Subhas Sarovar (SS) located in the heart of Calcutta city. Of these, one (RS) was identified as "National lake" under National Lake Conservation Programme (NLCP) by the Ministry of Environment and Forests, Government of India.

In this document efforts were made to ascertain the seasonal abundance and population fluctuation of macrophyte associated macrofauna along with physico-chemical factors of these two lakes under study. Special emphasis has been given to find out the interrelationship between abiotic and biotic factors and also among the biotic factors comprising of both macrophyte and macrofauna by statistical methods. Accordingly, statistical interpretations are made to understand the community structure and functional interrelationships between macrophyte and macrofauna, and the ecosystem processes involved therein. Furthermore, the findings of the physico-chemical factors as well as various biological indices, being indicative of 'health' and 'ecological status', may be used in developing/integrating management measures of these two lakes.

April 5, 2006
Kolkata

Sujit Pal
N.C. Nandi

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1. INTRODUCTION

Lakes are the most productive aquatic ecosystem. Besides acting as a life supporting system, they help to control water cycle and to regulate the environment. Urban freshwater lakes have an added role of recreational and aesthetic importance. In general, lake ecosystem possesses a vast array of diversity in its floral and faunal composition which are very much dynamic as well as responsive to the deviations from normal ecological homeostasis.

In lake ecosystem aquatic vegetation mainly macrophyte belonging to submerged, floating and emergent categories form an important element of the aquatic environment, universal in its significance for manufacturing food for aquatic heterotrophic communities. They also provide suitable surface area for shelter, site for oviposition, development, resting and nesting ground in addition to ambient weather and hiding places for macroinvertebrates, Pisces and other aquatic life. Several organisms like to congregate in weedy areas for feeding and breeding (Jones and Sujansingani, 1954; Ramamohana Rao and Kaliyamurthy, 1974). The macrophytic vegetation contributes to enrich the dissolved oxygen content of water during daytime and harbours a wide variety of macrofauna, which form the food of fishes and prawns. When the weeds get uprooted and are afloat, the associated fauna get dispersed in the lake (Patnaik, 1971; Ramamohana Rao, 1974). However, macrophytes in an aquatic ecosystem synthesise basic organic elements and ultimately contribute to the detritus pool of the bottom soil when they die.

The studies on macrophyte-associated macrofauna have received increased attention of wetland ecologists because of their functional role in the trophic dynamics. These macrofauna, besides being useful in enhancing the aquatic resource are also important in food chain leading to fishes and play an important link in energy transfers in lake ecosystems and take part in biological purification of water. They are, therefore, important and useful for the management of fish and waterfowl, and even used to demonstrate 'health' of the lakes.

In India, urban lakes have undergone critical changes in recent years, largely due to rising pressure on land and lack of awareness about their benefits and function. Lakes of urban Calcutta (now Kolkata), West Bengal have multifarious functions in microclimate stabilisation, nature conservation, recreation, reservoir of water, land and water sports, fire fighting, ecotourism and a wide variety of uses for the local communities (Nandi, 2000). Besides greenery, cool breeze and beauty of the lakes and openland in congested Calcutta, the ideal values of Calcutta lakes seem to be recreational in Rabindra Sarovar (RS) and game fishing in Subhas Sarovar (SS). It is worth mentioning that RS has attained the status of 'National Lake' in March 1997, as the eleventh entry in the National Lake Conservation Programme (NLCP) of the Ministry of Environment and Forests, Government of India. The NLCP proposes to augment the ongoing programme on wetlands by

undertaking large scale conservation activities in selected lakes including those which are not covered under the existing scheme on conservation and management of wetland of the Environment Ministry. The NLCP of the selected lakes would be centrally sponsored scheme with equal cost sharing on capital works by the Centre and participating State Government in which the operation and maintenance cost shall be borne by Concerned State Government (vide Annual Report 1995–96, Ministry of Environment and Forest, Govt. of India). As a part of this programme, the present study has been undertaken on RS and SS with special reference to lake water quality and aquatic phytofaunal community of these two lakes.

Furthermore, in India Lake ecosystem study dealing with macrophytal macrofauna is poorly available in a few States of Uttar Pradesh, Bihar, and Rajasthan (Laal, 1989; Singh and Roy, 1991; Singh 1989; Pandey *et al.*, 1994; Prakash *et al.*, 1994), while from West Bengal Michael (1964) had made some specific study of organisms associated with *Eichhornia crassipes*. So, to supplement the present knowledge in this subject, two urban freshwater lake ecosystems have been chosen for conducting fortnightly surveys during 1996 – 1998, making inventory, population and ecological studies of macrophyte associated macrofauna in relation to sixteen limnological parameters along with biotic factor and biological indices. Various computer simulation studies of multispecies food webs have been carried out, as the biotic factors are much more important than the abiotic factors in the environment. The influences of biotic interactions override the control of the latter (Menge and Sutherland, 1987). Hence, in the present study statistical analysis has been made to find out the interrelationship between biotic and abiotic factors and also within biotic factors. Such studies are likely to provide interesting insights on the interaction between macrophytes and their associated macrofauna. Practically nothing is known about the association of macrofauna with macrophytes of the freshwater wetlands of West Bengal. In view of such paucity of information on the subject, a detailed investigation on the community structure as well as relative abundance of phytal fauna has been carried out. However, much emphasis has been given to the most dominant groups *viz.*, Crustacea, Insecta and Mollusca playing the key role in the neverending symphony of aquatic phytofaunal diversity.

The main objectives of this research work are summarised as follows :

- To study the macrofaunal community associated with macrophytes of two urban freshwater lakes in Calcutta.
- To understand the ecological inter-relationship between macrofauna and macrophytes of these two selected lake ecosystems.
- To find out the influence of abiotic factors and the role of macrophytes on the associated macrofaunal groups/species of these two lake ecosystems using statistical methods.
- To assess the different population attributes with special reference to community diversity
- To highlight the ecological status of the selected urban lakes.

LIST OF ABBREVIATIONS

Abbreviations used in text and tables are listed hereunder.

For Physicochemical Parameters

Amon	= Ammonium.
At	= Air temperature
BOD	= Biochemical Oxygen Demand
Cl	= Chloride
COD	= Chemical Oxygen Demand
Con	= Conductivity
DO	= Dissolved Oxygen
FCO ₂	= Free Carbon di Oxide
Hard	= Hardness
NO ₂	= Nitrite
NO ₃	= Nitrate
pH	= pH
PO ₄	= Phosphate
TA	= Total Alkalinity
TDS	= Total Dissolved Solid
Tur	= Turbidity
Wt	= Water temperature

For Macrophytes

Alt	= <i>Alternanthera philoxeroides</i>
Cer	= <i>Ceratophyllum demersum</i>
Eic	= <i>Eichhornia crassipes</i>
Em	= Emergent macrophyte
Fm	= Floating macrophyte
Lud	= <i>Ludwigia adscedens</i> (= <i>Jussiaea repens</i>)
Mm	= Marginal macrophyte
Pis	= <i>Pistia stratiotes</i>
Sm	= Submerged macrophyte
T.Mac	= Total Macrophyte
Val	= <i>Vallisneria spiralis</i>

For Macrofauna

Ab	= <i>Anisops breddini</i>
An	= <i>Ambassis nalu</i>

Ap	= <i>Agriocnemis pygmaea</i>
Ape	= <i>Amphiops pedestris</i>
Ara	= Arachnida
As	= <i>Anopheles</i> sp.
Bb	= <i>Bellamyia bengalensis</i>
Bba	= <i>Badis badis</i>
Bc	= <i>Brachythemis contaminata</i>
Bi	= <i>Berosus indicus</i>
Biv	= Bivalvia
Brc	= <i>Brotia costula</i>
Bs	= <i>Branchiura sowerbyi</i>
Ca	= <i>Caridina</i> sp.
Cc	= <i>Ceragrion coromandelianum</i>
Cf	= <i>Colisa fasciata</i>
Ck	= <i>Cloeon kimminsi</i>
Cl	= <i>Canthydrus laetabilis</i>
Cls	= <i>Clypeodytes</i> sp.
Col	= Coleoptera
Cr	= <i>Chanda ranga</i>
Crus	= Crustacea
Cs	= <i>Chironomus</i> sp.
Cst	= <i>Channa striatus</i>
Da	= <i>Diplonychus annulatus</i>
Dc	= <i>Digoniostoma cerameopoma</i>
Dip	= Diptera
Dr	= <i>Diplonychus rusticus</i>
Du	= <i>Dineutus enidentatus</i>
Eph	= Ephemeroptera
Es	= <i>Enocrus</i> sp.
Gas	= Gastropoda
Gg	= <i>Glossogobius giuris</i>
Gl	= <i>Gyraulus labiatus</i>
Go	= <i>Gabbia orcula</i>
Ha	= <i>Helochares anchoralis</i>

Hem	= Hemiptera	Pc	= <i>Pisidium clarkeanum</i>
Hg	= <i>Hydrometra greeni</i>	Pe	= <i>Placobdella emydae</i>
Hir	= Hirudinea	Pg	= <i>Plia globosa</i>
Hma	= <i>Hemiclepsis marginata asiatica</i>	Pis	= Pisces
Hs	= <i>Hydrocoptus subvittulus</i>	Pl	= <i>Plea liturata</i>
Ia	= <i>Ischnura aurora</i>	Pm	= <i>Pseudagrion microcephallum</i>
Ie	= <i>Indoplanorbis exustus</i>	Pp	= <i>Pardosa pusiota</i>
Ir	= <i>Ictinogomphus rapax</i>	Pph	= <i>Puntius phutunio</i>
Is	= <i>Ischnura senegalensis</i>	Ps	= <i>Plea</i> sp.
La	= <i>Lymnaea accuminata</i>	Ra	= <i>Regimbertia attenuata</i>
Lg	= <i>Laccotrephes griseus</i>	Rf	= <i>Ranatra filiformis</i>
Lh	= <i>Limnodrilus hoffmeisteri</i>	Rs	= <i>Ranatra sordidula</i>
Lip	= <i>Laccophilus parvulus</i>	Sr	= <i>Sternolophus rufipes</i>
Ll	= <i>Lymnaea luteola</i>	Ss	= <i>Sartoriana spinigera</i>
Lm	= <i>Lamellidens marginalis</i>	T. Ins	= Total Insect
Lp	= <i>Limnogonus parvulus</i>	T. Macf	= Total Macrofauna
Ls	= <i>Laccophilus sharpi</i>	Tg	= <i>Thiara granifera</i>
Md	= <i>Macrobrachium dayanum</i>	Tl	= <i>Thiara lineata</i>
MI	= <i>Macrobrachium lamarrei</i>	Ts	= <i>Tetragnatha</i> sp.
Ms	= <i>Micronecta scutellaris</i>	Ts	= <i>Thiara scabra</i>
Od	= <i>Odontomyia dorsoangulata</i>	Tt	= <i>Thiara tuberculata</i>
Odo	= Odonata	Uq	= <i>Uvarus quadrilineatus</i>
Oil	= Oligochaeta		
On	= <i>Oreochromis nilotica</i>	General	
Os	= <i>Orthetrum sabina</i>	RS	= Rabindra Sarovar
Pa	= <i>Pardosa alii</i>	SS	= Subhas Sarovar
Pb	= <i>Pardosa birmanica</i>	NLCP	= National Lake Conservation Programme

2. EARLIER WORKS

Lake ecosystem studies and limnological researches have been the subject of intensive investigation by Forel, the father of limnology, whose monographic contributions on hydrology, hydraulics, biology as well as geology, physics, chemistry, etc., of Lake Geneva, Switzerland in 1892, 1895 and 1904, have heralded the whole science of freshwater ecology. However, Leslie (1838) was the first man to describe the role of light, heat, water temperature and wind mixing in lake ecosystem. Forbes (1887), on the other hand, was first to consider lakes as functional ecological systems. Brige (1915) is noteworthy for

contributing greater biological dimension to the field of limnology through his study on plankton of lakes in Europe and America. Several other workers are known to contribute immensely towards the limnology and benthic ecology all over the world (Welch, 1948,1952; Rawson, 1960; Beeton, 1965; Hutchinson, 1967; Herzig, 1979; Paerl and Payne, 1979; Sweeney, 1984; Gehrels and Mulamoottil, 1990; Di Givanni *et al.*, 1992; Antwi and Ofori - Danson, 1993; Mukankomeje *et al.*, 1993; Vidondo and Martinez, 1993; Dorgeloh *et al.*, 1994; Gopal and Wetzel, 1995, Sivaramakrishnan *et al.*, 1996; Finlayson and Froend, 1998; Deaver *et al.*, 2005).

In India, a large number of limnological studies have been made particularly in the past few decades on almost all kinds of aquatic habitats. Some earlier works on water quality and aquatic habitat include those of Hamilton (1822), Day (1878), Annandale (1907) and Hutchinson (1937 a). Distinct patterns of seasonal variation of physicochemical parameters were observed by Ganapati and Alikuni (1950), Ganapati and Chacko (1951), Iyenger and Venkatraman (1951), Chacko *et al.* (1953), Rao (1955), Singh (1955), Abraham (1962), George (1962), Sreenivasan (1964 a, b 1976), Lakshminarayana (1965), Ray *et al.* (1966), Hussainy (1967), Sahai and Sinha (1969), Munawar (1970), Rai (1974), Sharma *et al.* (1978), Jana *et al.* (1980), Michael (1980), Unni (1985), Khatavkar *et al.* (1989), Jakher *et al.* (1990), Sarwar and Wazir (1988, 1991), Varghese *et al.* (1992), Pandey (1993), Satpathy (1993), Tanti and Saha (1993), Gupta and Sharma (1994), Ramana and Sreeramulu (1994), Ghosh (1997) and Paria and Konar (1998).

However, the second half of the twentieth century gave impetus to studies on benthic fauna, as well as water quality by the luminaries of Indian limnology (Srivastava, 1956, 1959; Krishnamurthy, 1966; Michael, 1968; Patnaik, 1971; Mandal and Moitra, 1975a, b; Raman *et al.*, 1975; Gupta, 1976; Abraham, 1979; Mathew, 1979; Vasisht and Bhandal, 1979; Kaul and Pandit, 1981; Gupta and Pant, 1983, 1986, 1990; Balakrishna *et al.*, 1984; Yadava *et al.*, 1984; Rao *et al.*, 1987; Ahmad and Singh, 1989; Kaushal and Tyagi, 1989; Adholia *et al.*, 1990; Malhotra *et al.*, 1990; Singh and Roy, 1991a, b; Bais *et al.*, 1992; Barbhuyan and Khan, 1992, 1994; Singh and Sinha, 1993; Bose and Lakra, 1994; Singh and Singh, 1994; Kodarkar, 1995; Kaur *et al.*, 1996; Goel, 1997; Sharma, 1998; Shastri *et al.*, 1999; Dutta *et al.*, 1999).

Although considerable works have been made by researchers abroad very little information is known about macrofaunal community associated with macrophytes from Indian lakes. The pioneering endeavour on this particular subject of macrophytal macrofauna was also made by Forel (1904), the founder father of Limnology, in Geneva who emphasized the high degree of spatial heterogeneity among the macrophyte dwelling invertebrates. Moore (1915) first reported importance of macrophyte as food of invertebrates. Richardson (1921) while working on Illinois river and it's connecting lakes, Needham (1929) on Erie Niagra system showed that invertebrate fauna living on macrophytes were many times more abundant than those living in bottom sediments. The abilities of various plant species to support animal populations were studied in details by

Andrews and Hasler (1943), Krecker (1939), Entz (1947), Macan (1949), Rooke (1984) and Biochino and Biochino (1980). Use of aquatic plants by the insects as mechanical supports and site for oviposition has been pointed out by Beng (1950), Welch (1952), Minshall (1984) and Sheldon (1984). Faunal variations in different plant biotopes was occurred due to the available plant surface area, supply of food, degree of exposure, swarming and natural death as commonly reported by Rosine (1955), Stube (1958), Biggs (1982), Dejourx (1983), Scheffer *et al.* (1984), Schramm *et al.* (1987) and Chilton (1990). Gerking (1957) and Minto (1977) described the method of sampling of littoral macrofauna associated with aquatic vegetation. Mrachek (1966) studied the macroscopic invertebrates on the higher aquatic plants at clear lake, Iowa. Hutchinson (1967) coined the term epiphytic macroinvertebrates. Peter (1968) studied the population changes in aquatic invertebrates living on *Pistia stratiotes* and *Ceratophyllum demersum*. Mc Lachlan (1969, 1975) studied the effect of aquatic macrophytes on the variety and abundance of benthic fauna in a newly created lake in the tropics (Lake Kariba). Some of the important contributors in the field of macrophyte productivity were made by Davies (1970), Wong and Clark (1979). Krull (1970) and Arner *et al.*, (1974) showed the pattern of aquatic plant-macroinvertebrate association and their use in waterfowl management. Korinkova (1971) established the quantitative relationship between submerged macrophytes and invertebrates. Pieczyn'ski (1973) performed the experimental study on the number and biomass of the fauna associated with macrophytes. Temporal variations in the abundance of epiphytic invertebrates have been documented by Soszka (1975), Voights (1976) and Smock and Stoneburner (1980). Higler (1975) and Junk (1977) analysed the macrofaunal community on different strands of floating vegetation. Glowacka *et al.* (1976) and Gregg and Rose (1985) recorded the higher abundance of macroinvertebrates in vegetated zone rather than vegetation free zone. Pip and Stewart (1976) and Lodge (1985) worked on the dynamics of plant-snail association. Structural and functional relationships of macroinvertebrate communities associated with macrophytes have been described by Dvorak and Best (1982) in lake Vechten, Netherland.

The abundance of phytophilous invertebrates in relation to biomass of macrophytes has been reported by Biochino and Biochino (1980); Vincent *et al.* (1982), Keast (1984) and Downing (1986). Gilinsky (1984) reported that macrophyte sometime serve as a refuge towards the macroinvertebrate from predators. Downing (1986) proposed a regression equation method for estimation of population of epiphytic invertebrates. Diversity of macroinvertebrate and macrophytes in pond ecosystem was reported by Friday (1987). Benthic weed bed fauna of lake Awasa, Ethiopia were reported by Kibert *et al.* (1989). Hargeby (1990) emphasised the importance of habitat permanance in case of macrophyte associated invertebrate. Hanson (1990) explained the size distribution of macroinvertebrate on two contrasting freshwater macrophyte communities in Canada. Ryszard and Gulati (1992) worked on the macrofaunal changes inhabiting on hydrophytes, after biomanipulation in the Netherlands. Parsons and Matthews (1995) studied the complex association between macrophytes and macroinvertebrates in a freshwater pond of Washington.

In India very limited number of workers attempted to study the macrophyte associated macrofauna (Laal, 1989; Singh and Roy, 1991). But Srivastava (1955, 1956) initiated the study on bottom fauna of fish tanks in Uttar Pradesh. Govind (1978) explained about the bottom fauna, macrovegetation and their role in the food chain of fish communities. Rai and Datta Munshi (1978, 1980) studied on the community structure of aquatic macroinvertebrates associated with different types of weed communities. Rai, Roy and Sharma (1981) on the other hand studied only on the gastropod community in relation to macrophytes of littoral zone of a fish pond at Bhagalpur (Bihar). Roy and Sharma (1982) indicated the role of aquatic insect as a bio-indicator of pollution. Rao and Jain (1985), Roy et al. (1986) and Srivastava (1986) demonstrated use of macrobenthos as well as aquatic insects for water quality monitoring. A detailed study on weed associated macrofauna of an ox-bow lake in Allahabad (Uttar Pradesh) made by Singh (1989). Laal (1989) reported the composition and numerical dynamics of invertebrates associated with *Eichhornia crassipes*, *Trapa bispinosa*, *Elodea* spp. and *Vallisneria* spp., from different fish ponds at Bhagalpur (Bihar). Aquatic insect community study in ponds of Gwalior (Madhya Pradesh) was made by Saxena et al. (1989). Similar type of work was carried out by Sharma et al. (1991) in Bhagalpur, Sinha and Roy (1991) in Dumkas lake and Kumar and Roy (1994) in Bihar. Singh and Roy (1991) classified the macroinvertebrates based on the degree of association with the macrophytes as 'associated', 'less associated' and 'not associated'. Rai and Sharma (1991) documented correlation between macrophytic biomass and macroinvertebrate community structure in wetlands of North Bihar. Mishra et al. (1992) made a detailed account of insect association with *Euryale ferox* Salisbury in five ponds of Darbhanga, North Bihar. Kumar and Mittal (1993) made habitat preference of fishes in relation to aquatic vegetation and water chemistry in a monsoonal wetland of Keoladeo National Park, Bharatpur, Rajasthan. Jamil (1993) emphasized the role of macrophytes in aquatic ecosystem. Potentiality of *Azolla pinnata* as fish feed was explained by Das et al. (1994). Relationship of weed fishes with macrophytes in Kavar lake (Bihar) was reported by Prakash et al. (1994). In the same lake, Pandey et al. (1994) showed that gastropods had significant positive correlation with macrophytes. Sinha and Sharma (1996) made detailed account of interactions of nutrients between biotic and abiotic component.

In West Bengal, Michael (1964) listing the organisms associated with *Eichhornia crassipes* made initial attempt in this field. Though studies on faunal resource including macrobenthos were made by several workers (Mondal and Moitra, 1975; Datta and Sarangi, 1980; Sarkar, 1989, 1992; Ghosh and Chattopadhyay, 1990, 1994; Nandi et al., 1993, 1994, 1999, 2001, 2005; Ghosh and Banerjee, 1996; Sinha and Khan, 1998; Mukherji et al., 1998; Mukherji and Nandi, 2004). Julka (1977) reported on the seasonal abundance and population fluctuation of different aquatic insects. Bhattacharya and Gupta (1991) and Chakraborty and Saha (1993), however, surveyed the physicochemical and hydrological features of the stagnant water bodies in Darjeeling. Ghosh and Banerjee (1996) performed considerable statistical work on macrobenthic faunal diversity of two freshwater pisciculture ponds of Sonarpur, West Bengal. Mitra (1997) made a generalised view that macrophyte associated fauna form a major link in the food chain of floodplain lakes. Pal

and Nandi (1997) constructed a simple device for quantitative sampling of macrofauna from littoral macrophytes. Bhattacharya (1998) and Pal *et al.* (1998) attempted to study the insect diversity associated with macrophytes of some waterbodies in West Bengal. Nandi *et al.* (2001) observed that high plant diversity supports higher faunal diversity in the King Lake of Indian Botanical Garden, West Bengal. However, it is important to note that no qualitative, quantitative and/or ecological study on macrophyte associated macrofaunal community was made so far from these two lakes (RS and SS) under study.

3. MATERIAL AND METHODS

3.1. Study area

3.1.1. Topography

Calcutta (now Kolkata) is located on the left bank of Hugli-Bhagirathi river and is a part of mature Ganga delta, approximately 6 metre above the sea level (Fig 1A). The topographical features of Calcutta, derived principally from the interaction of rivers of the Gangetic system and the sea, include a number of wetlands scattered all over the region with the urban, industrial and rural life of the area (Ghosh and Sen, 1988). The major wetlands of Calcutta are located between the latitudes 22°25' - 22°40' north and longitudes 88°20' - 88°35' east.

Amongst the urban waterbodies, Rabindra Sarovar (RS) and Subhas Sarovar (SS), popularly known as Dhakuria Lake and Belegghata Lake respectively, are infact the right and left lungs of the congested Calcutta metropolis proper situated in the south and east Calcutta respectively. Both the water bodies or lakes are artificial reservoirs, mainly feed by rainwater and are maintained by the Calcutta (Kolkata) Improvement Trust (CIT now KIT).

3.1.2. Ecological History

From the second decade of the twentieth century, CIT undertook a programme of extending the city southward and eastward by acquisition of marshyland. In the process, large excavations were undertaken and eventually 1940 and 1964 developed these two lakes, RS and SS with new roads, parks and neighbourhoods respectively. Gradually, various other features like swimming arena, football and athletic grounds etc., were added inside the lake complex. During 1950's many residential settlements around RS were developed further south of Calcutta when a large population from East Pakistan (now Bangladesh) migrated to India. The settlements in the surrounding areas of SS expanded during 1970's with the progress of reclamation of the Salt Lake for extension of the city in the east.

3.1.3. Morphometric measurements

The land and water area of RS and SS are about 119 and 73 acres respectively. The maximum length of RS is about 1770 m and maximum width at its broadest part is

286 m (Fig 1B). The perimeter of this lake about 18,000 Rft., while mean depth varies from 9-10 meters. The lake SS, has an area of 39.5 acres only (Fig 1C). The length of SS from west to east is 533 m and the breadth from south to north is 366 m.

3.1.4. Status and usage pattern

At present both the lakes possess multifarious features for waterfront recreation, land and water sports, swimming, washing, bathing, domestic use of water etc., the open space is used for playing games, doing physical exercise, travelling, refreshing and for morning walk. In addition to these, SS is widely used for game fishing purpose. Here angling is held almost throughout the year except for a few months (June - July) when the fingerlings are released into this lake.

These two artificial waterbodies suffer from rapid urbanisation and large-scale human interference. The residents of the adjoining slum areas of RS and SS over the years use the lake waters for bathing and washing of clothes and utensils etc. They have developed the practice of defaecating in the open on the embankments and use the lake water for afterwash. Due to excessive human usage there has been considerable soil erosion especially along the banks. The lakes have been increasingly converted into dumping sites of domestic wastes. Occasionally carcasses are disposed in the lakes. However, RS has recently been elevated to the status of the 'National lake' in 1997, under the National Lake Conservation Programme (NLCP) set up by the union Ministry. As a result there has been increasing improvement of lake environment in RS and SS and treatment of catchment area, dewatering, desilting and research and developmental studies on lake ecology towards lake environment management.

3.2. Sampling sites/stations

To study the macrofaunal community associated with macrophytes, regular sampling of water and biota was done fortnightly during 1996-98 from three selected sites/stations of each lake as follows:

RABINDRA SAROVAR

Station 1 : Located at Block 'D' of the lake in a shady and undisturbed place with dense floating and patchy submerged macrophytes.

Station 2 : Located at Block 'A' of the lake in a place exposed to sunlight, partly disturbed and devoid of floating vegetation but with uniform submerged vegetation.

Station 3 : Located at Block 'A' on the opposite bank of Station 2, in a partially shady mostly and undisturbed place with diversified/polyspecific vegetation.

SUBHAS SAROVAR

Station 1 : Located at the western side of the lake exposed to sunlight in a partly disturbed place devoid of floating vegetation but with dense submerged vegetation.

Station 2 : Located at the southern side of the lake in a partially shady and mostly undisturbed place (except game fishing) with diversified/polyspecific vegetation.

Station 3 : Located at the northern side of the lake in a shady and undisturbed place with some floating vegetation but uniformly dense submerged vegetation.

3.3. Data collection and analysis of abiotic components

3.3.1. Collection of atmospheric/meteorological data

Temperature of air was recorded by a digital centigrade thermometer (-50 to +150°C) on the date of sampling. Besides maximum and minimum air temperature, relative humidity and rainfall in Calcutta, during the study period (1996–98) were collected from the Meteorological Office, Calcutta. The average values of the data recorded during the period 1996–1998 were represented on a monthly basis to get an overview of the climatic condition of Calcutta.

3.3.2. Collection and preservation of water samples

Water samples were collected fortnightly in clean glass bottles from vegetated zone of three different sites/stations of each lake. Water samples were collected in three replicates from surface, column and bottom of each station and mean values of all these observations were taken into consideration. For BOD estimation, water samples were collected separately in dark bottles.

Physico-chemical parameters like water temperature, pH, dissolved oxygen, free carbon-di-oxide, total alkalinity, conductivity were measured in the field. Other parameters were mostly tested within 24 hours of collection. Preservation of water samples was done at 4°C temperature.

3.3.3. Analysis of water sample

A total of 16 limnological parameters *viz.*, temperature, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), free carbon-di-oxide, pH, total alkalinity, conductivity, total dissolved solid, total hardness, turbidity, chloride, phosphate, nitrite, nitrate and ammonium were determined.

All the parameters were analysed following the standard methods (Michael, 1984; Trivedy and Goel, 1984 and APHA, 1989) and by spectrophotometer SQ 118.

Temperature of water was recorded by a digital centigrade thermometer (-50 to +150°C). Azide modification of Winkler's iodometric method (APHA, 1989) was applied for testing the dissolved oxygen content of water. BOD was estimated by measuring the amount of oxygen consumed by the sample in five days in dark at 20°C (APHA, 1989). COD estimation was done by refluxing the sample with potassium dichromate and sulphuric acid and

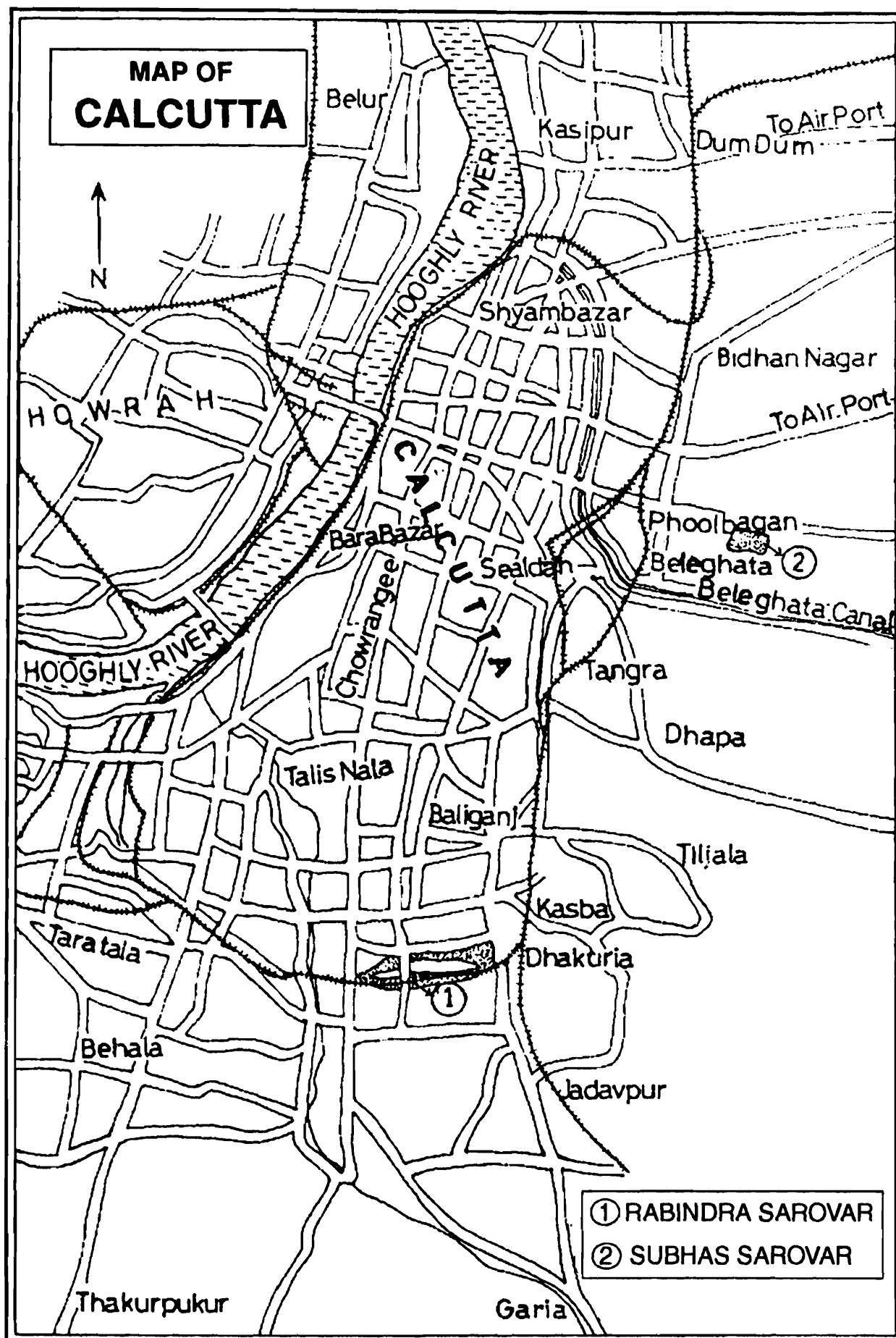


Fig. 1A. Map of Calcutta showing the location of Rabindra Sarovar and Subhas Sarovar.

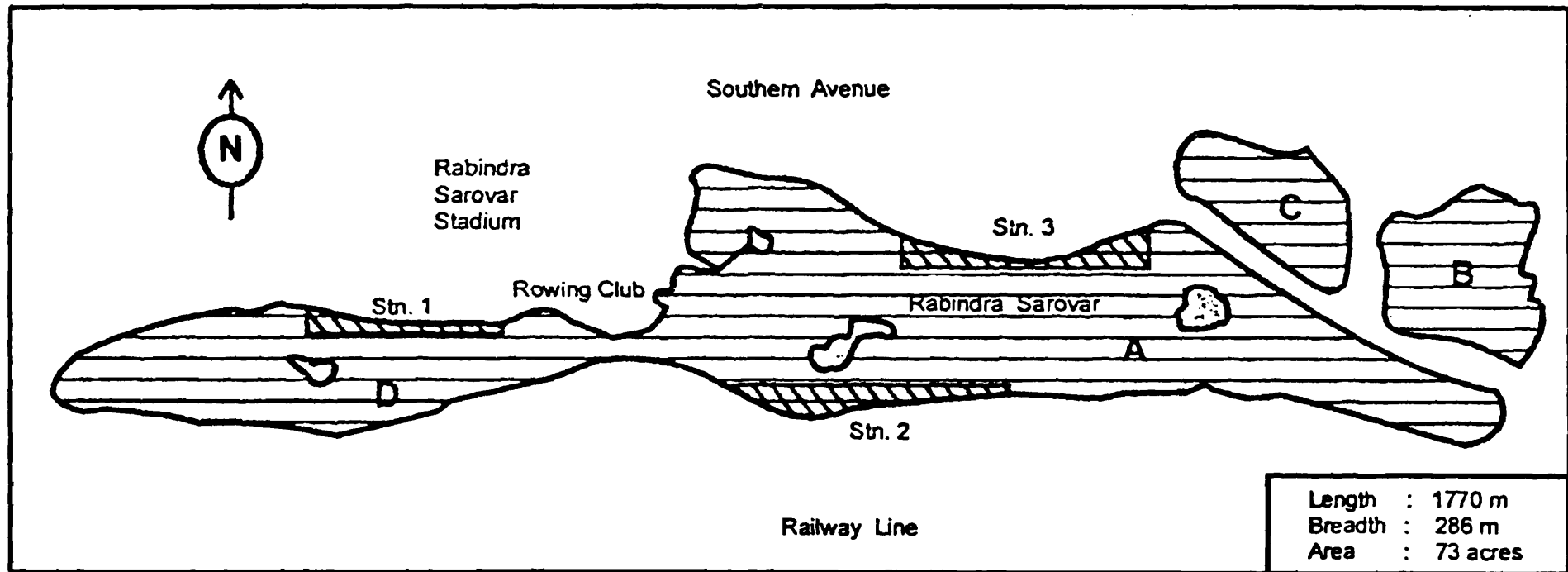


Fig. 1B. Map of Rabindra Sarovar showing sampling stations.

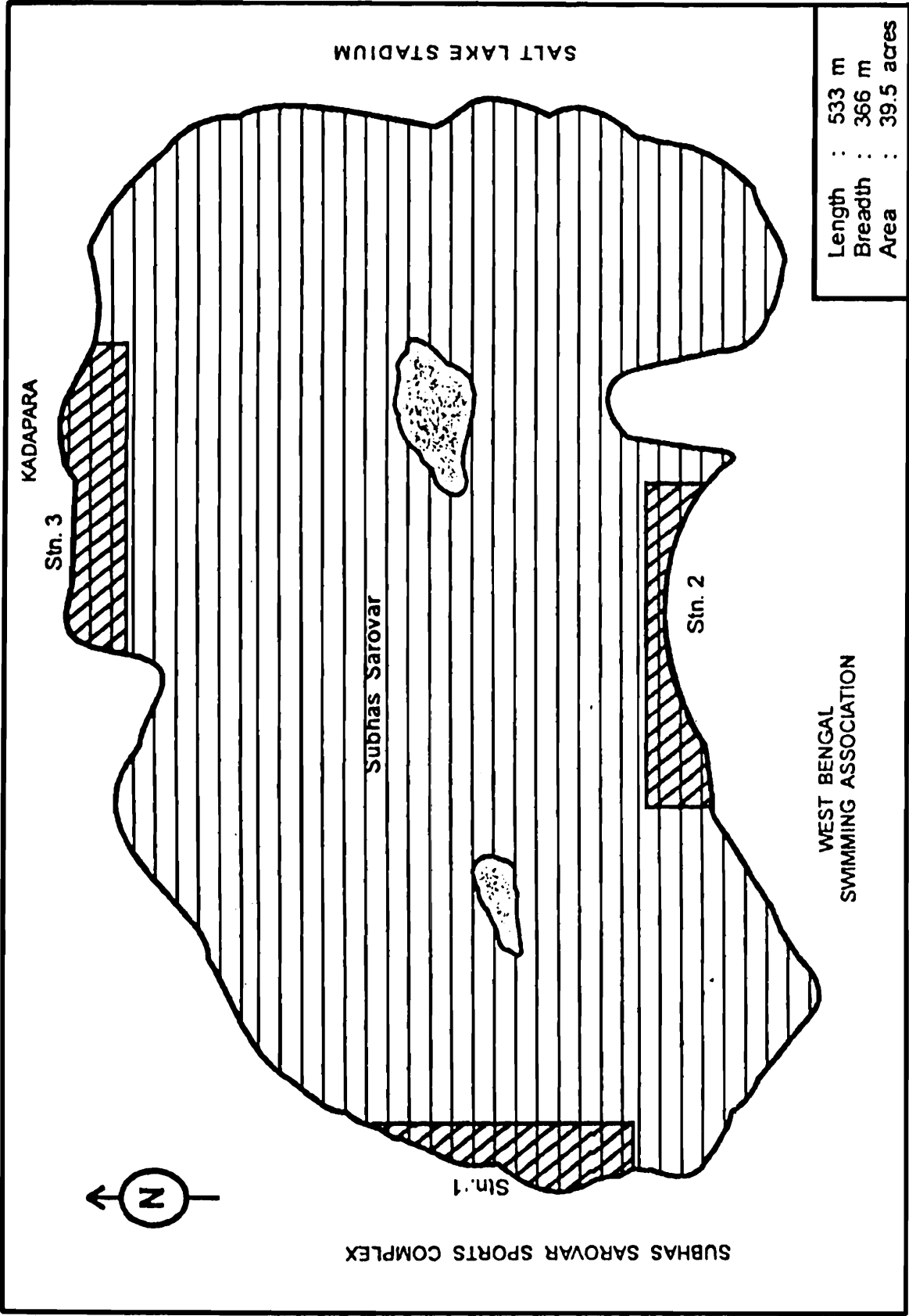


Fig. 1C. Map of Subhas Sarovar showing sampling stations.

then titrating the residual potassium dichromate against ammonium ferrous sulphate using ferroin as indicator (APHA, 1989). Using Phenolphthalein indicator free carbon-dioxide was measured by titrating 100 ml of sample solution by 0.0227 N NaOH (Michael, 1984). pH was determined by pH meter (model pH 320, Merck, Germany). Total alkalinity was determined by titrating 20 ml of water sample with 0.02 N sulphuric acid using Phenolphthalein and methyl orange indicator (APHA, 1989). Conductivity and total dissolved solid was measured by conductivity meter (model LF320, Merck, Germany). Total hardness was measured by EDTA titrimetric method (APHA, 1989) where the water sample was titrated with 0.01M EDTA titrant using Eriochrome black T dye and sodium chloride as a dry powder indicator. Turbidity values were determined by spectrophotometer SQ 118. Chloride was measured following Argentometric method (APHA, 1989), where 0.0141 N silver nitrate solution was used to titrate the water sample with potassium chromate indicator solution. Phosphate (ortho) was measured by Ascorbic acid method (APHA, 1989). Phosphate reacts with ammonium molybdate to form molybdophosphoric acid. This is transformed by reductants to form a blue complex that was recorded spectrophotometrically. Nitrate was determined colorimetrically following Phenol-disulphonic Acid method (APHA, 1989). Nitrite was also estimated colorimetrically by developing a colour with EDTA, sulphanilic acid, naphthylamine hydrochloride and sodium acetate (APHA, 1989). Nesslerization method was followed for estimation of ammonium. Zinc sulphate and sodium hydroxide were added to the sample and one drop of EDTA was added along with Nessler's reagent, to develop the colour that was measured (APHA, 1989).

3.4. Data collection and study of biotic components

3.4.1. Collection of macrophyte and associated macrofauna

Data on the biotic component of these two lakes were collected by fortnightly sampling from each lake along the littoral zone extending from the lake margin to about 4 m from the shore, usually delimited by rooted aquatic vegetation.

The macrophytic sample specimens were manually collected for making inventory and for identification of the species. Qualitative samplings of macrophyte and macrofauna were made seasonally by means of hand picking, drag netting and by a box type sampler of 20 x 20 x 40 cm³ size (Fig. 2; Pal and Nandi, 1997) at different depth of the three selected stations of each lake. In total 9 samples were taken fortnightly from each station and in all 27 samples from each lake for effective evaluation of the data. The macrophytes enclosed in the sampler were soon washed thoroughly in waters so as to isolate the fauna completely from weeds and subsequently filtered through a standard sieve of 0.5 mm. mesh size (Jonasson, 1955; Havgaard, 1973; Parsons and Mathews, 1995). Macro-organisms retained in the sieve are brought to the laboratory and are sorted in a large enamel tray in fresh condition. The sorted organisms are preserved in 70% alcohol. Herbaria of macrophytes were also prepared as and when required for proper identification.

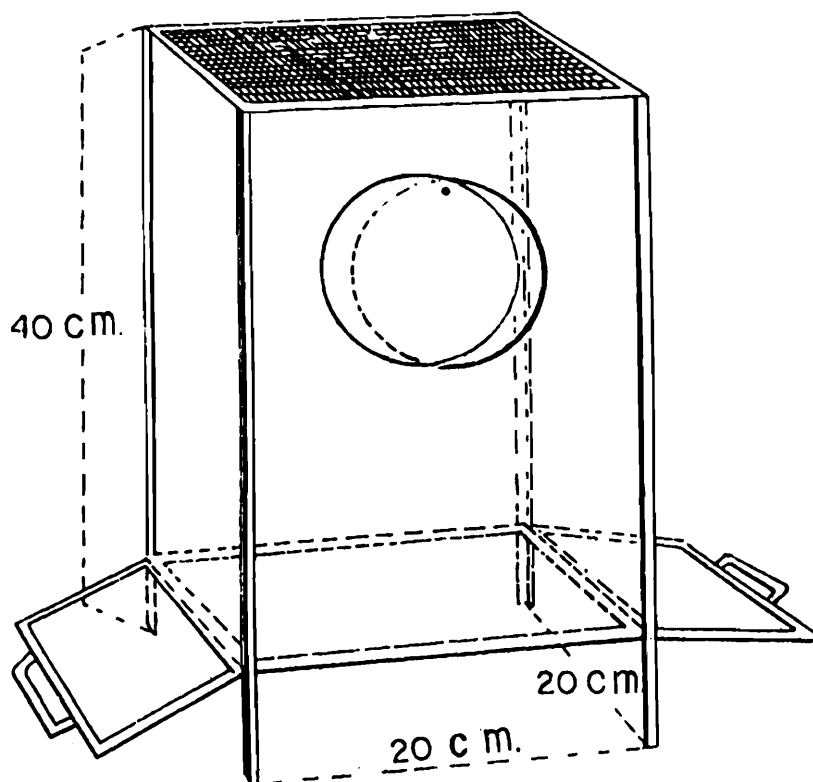


Fig. 2. Sketch showing sampler used for sampling of macrofauna associated with macrophytes.

3.4.2. *Identification of macrophytes and macrofauna*

Identification of preserved macrophytes were done initially with the help of expert of the Botanical Survey of India as well as consulting available literatures (Biswas and Calder, 1936; APHA, 1989), while experts of the Zoological Survey of India as well as abroad at the beginning identified the representative macrofauna associated with the macrophytes to establish a ready reference collection. Subsequently, the sampled specimens were identified using the reference collection and available literature (Tonapi, 1980; Srivastava, 1993; Jayaram, 1981; Subba Rao, 1989; De and Sengupta, 1993).

3.4.3 *Determination of population density and percentage frequency*

Population density represents the number of individuals per unit area. In present study the number of macrophyte associated macrofauna (groups/species) was expressed as number of individuals per meter square using the formula put forwarded by Welch (1948)

$$n = \frac{o}{a \times s} \times 10,000$$

where,

n = number of organisms per metre square

o = number of organisms counted

a = area of the sampler

s = number of replicates taken

Percentage frequency is the percentage of quadrats in which a given species is found and is determined as follows :

$$\text{Percentage frequency} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats}} \times 100$$

3.4.4. Estimation of biomass

The biomass was determined as dry weight. Wet weight biomass was measured immediately after soaking of water using a blotting paper, and for dry weight biomass samples were oven dried at 60°C for 48 hours (Rai and Sharma, 1991). The dry weight of macrofaunal specimens was determined by drying the animal in a drying oven at 105°C for 24 hours, cooled in and weighed (Winberg, 1971).

3.4.5. Community analysis

Five biological indices viz., Shannon's index of diversity (Shannon-Weiner, 1949), Species richness (Margalef, 1958), Index of dominance (Simpson, 1949), Evenness index (Pielou, 1966) and Index of similarity (Sorensen, 1948) were calculated. The percentage similarity values between the stations, in a dendrogram were constructed following the method used by Mountford (1962). Details about the formula of community analysis are given in chapter 4.8.

3.4.6. Statistical calculations

A two-way analysis of variance (ANOVA), after transforming the value of each data to $\log(x + 1)$ was calculated to find out the significance of the differences in density of the macrofaunal groups among the different macrophytes, stations, seasons and lakes.

Pearson's correlation coefficients were calculated to evaluate the parametric relationships between the abiotic and biotic factors supposedly in interaction. The tests were all two tailed and the correlation were tested at 5% and 1% level of significance. In aquatic ecosystem the life cycle and abundance of macrofaunal organism are controlled by various physicochemical factors of water as well as macrophytic growth. To analyse the relationship stepwise multiple regression method was adopted. Thus we had to choose a 'p'-x variable (Physicochemical parameters/macrophyte density and biomass) that could best predict the response of Y (macrofaunal density and biomass).

The ultimate linear model used is –

$$Y_{ij} = \beta_0 + \sum_{j=1}^p \beta_j X_{ij} + \epsilon_{ij}$$

Where,

β_0 = intercept of the model

β_j = partial regression coefficients of the j th parameter after eliminating the effect of the parameters other than j th one ($j = 1, \dots, p$)

X_{ij} = independent parameters

ϵ_{ij} = random error component

Least square method is used to estimate the unknown (β 's at each step of selection. This is a universal selected statistical procedure in which the only random variable is Y and X 's are treated as non-random. The significance of (β_j 's has been tested with help of t -statistics. The square of multiple correlation coefficient, R^2 , for each model indicates the variation in density explained by the P -variable. The significance of R^2 is tested with the help of F -statistics. The whole analysis was carried out with the help of a relevant software programme under SPSS, version 6.0.

3.5. Abbreviation used

In text, tables, figures etc. of this document abbreviations of various physicochemical and biological parameters are used, the full names of these abbreviations are listed in pages 3–4 above.

4. RESULT AND DISCUSSION

4.1 Climatic condition

Premonsoon, monsoon and postmonsoon i.e., summer, monsoon and winter are the three distinct seasons of tropical countries including India. In Calcutta, the capital city of West Bengal, premonsoon or summer season (February–May) has higher air temperature, longer day length and occasional rain. On the other hand, the monsoon period (June–September) is characterised by relatively shorter hours of sunshine, high humidity and appreciable rainfall. The month June marks the onset of monsoon, which retreats by October with the advent of autumn with moderately hot day temperature and cooler night. However, the postmonsoon or the winter season is referred herein from October to January, which may extend to February. It is characterised by low air temperature, shorter day length and less precipitation.

Air temperature

The maximum monthly mean air temperature was 37.5°C in April, 1997 and minimum monthly mean was 14°C during January, 1998. Range of variation of temperature during various months of the year (1996–1998) under study is shown in Fig. 3.

Total rainfall

Highest rainfall was observed in August, 1996 (626.5 mm) and lowest rainfall was recorded in January, 1997 (1.9 mm). Total monthly rainfall is represented in Fig. 3.

Humidity

The percentage of relative humidity was highest during August 1996 (89.5%) which corresponds with the period of maximum rainfall. Lowest humidity was noticed in April 1997 (50%).

From the Figure 3. it is revealed that the climate of Calcutta is characterised by a distinct seasonality of rainfall, dry summer period and comparatively cooler winter season.

4.2 Physicochemical factors of the lakes

The detected values of all the 17 physico-chemical parameters are shown monthwise in Fig. 4 (A-H), whereas the range and mean values of each parameter for each lake are given in Table 1.

Air temperature (At)

The atmospheric temperature had a significant role in regulating/fluctuating various physicochemical as well as biological parameters. Temperature showed highest value in summer (33.66°C in RS and 33.93°C in SS) and lowest values in winter (18.83°C in RS and 16.2°C in SS).

Water temperature (Wt)

It was fluctuated from 19.2°C (January) to 33.1°C (May) in RS and 18.67°C (January)-33.93°C (May) in SS. Both the lakes show winter minima and summer maxima. Average values tend to be similar in these two lakes.

The water and air temperatures were found to go more or less hand in hand presumably due to standing water and relatively small size of the water body. According to Welch (1952) smaller the body of water, more quickly it reacts to the changes in the atmospheric temperature. Sharma and Gupta (1994) also observed positive correlation between air and water temperature.

Dissolved Oxygen (DO)

The DO values ranged from 5.1- 9.98 mg/l in RS and 4.81-8.94 mg/l in SS. The average values was slightly higher in RS (6.85) than SS (6.26). This was probably due to higher macrophytal diversity and density in RS than SS. Average values suggest the mesotrophic quality of water in both the lakes (Rana and Kumar, 1993).

These two lakes showed maximum gradient of dissolved oxygen in winter and minimum in the monsoon months which is due to better oxygen holding capacity of water at low temperature in winter, and not so, due to inadequacy of sunlight together with increased turbidity of water during monsoon (Gupta and Sharma, 1994).

Biochemical Oxygen Demand (BOD)

BOD values ranged from 4.0 mg/l (January) to 10.5 mg/l (April) in RS and 5.5 mg/

l (November) to 13.5 mg/l (May) in SS. Low values of BOD in winter may be due to lesser quantity of total solids/dissolved solids/suspended solids (Rice, 1938; Zafar, 1966; Zutshi and Vass, 1982). This observation agrees with the findings of Pathak and Shastree (1993) and Sharma and Rajput (1994).

Chemical Oxygen Demand (COD)

It was minimum in winter (18.5 mg/l in RS and 11.5 mg/l in SS) and maximum in summer (49.1 mg/l in RS and 77.5 mg/l in SS). Like BOD, COD was also higher in SS (32.14) than RS (28.33). Increase of COD in summer is in accordance with Goel *et al.* (1980) and Varghese *et al.* (1992).

Free Carbon di Oxide (FCO₂)

A state of inverse relationship between CO₂ and DO was observed during the study period. Interestingly, DO minima witnessed a higher CO₂ profile, 2.6 mg/l in July in RS and 2.8 mg/l in August in SS. The minimum value of FCO₂ observed in January in both the lakes (0.05 mg/l in RS and 0.25 mg/l in SS). The depletion of FCO₂ may be accounted for its dependence on photosynthetic process, involvement of some marl-forming organisms, evaporation and rise of bubbles from depth (Welch, 1957). Average FCO₂ content is lower in RS (1.27 mg/l) than SS (1.35 mg/l) due to higher macrophytic density in RS.

pH

It ranged between 7.41 and 9.48 in case of RS and between 6.81 and 8.83 in case of SS, and mostly remained alkaline throughout the period of investigation (1996-1998) as observed by Sarwar and Wazir (1991), Kartha and Rao (1992) and Kumar (1995). It virtually showed very little variation on monthly basis. Though the average value was somewhat higher in RS (8.23) than SS (8.04), the alkaline nature of these two lakes indicate considerable photosynthetic activity and regular entry of cloth washing wastes in both the lakes.

Total Alkalinity (TA)

Total alkalinity was higher in monsoon (493 mg/l in RS and 345 mg/l in SS) and lower in winter (250 mg/l in RS and 185 mg/l in SS). In monsoon cloudy sky decreases the rate of photosynthesis and eventually CO₂ rich aquatic medium inhibits the decomposition of bicarbonates. The presence of high bicarbonates increases the total alkalinity of water (Kaur *et al.*, 1995). During winter, due to slow decomposition of organic matter, CO₂ production is less. Furthermore, the clear days lead to higher photosynthetic activity and increasing utilization of FCO₂. All these factors collectively deplete the bicarbonate level, which ultimately reduce the alkalinity in water. Average values were higher in RS (356.42 mg/l) than SS (241.67 mg/l) indicating higher trophic status of RS (Philipose, 1959 and Spence, 1964).

Conductivity (Con)

It varied from 311.5-805 $\mu\text{mhos/cm}$ in RS and 243-605 $\mu\text{mhos/cm}$ in SS and, in general it is higher in RS (583.54 $\mu\text{mhos/cm}$) than SS (401.24 $\mu\text{mhos/cm}$). Conductivity decreased during winter followed by progressive increase in summer as also recorded by Sharma *et al.* (1978), Varghese *et al.* (1992), Pathak and Shastree (1993). This is due to the increased salt concentration caused by evaporation in summer. Low values in winter may be due to the dilution effect of rainfall (Trivedi *et al.*, 1985).

Hardness (Hard)

The average value was higher in RS (104.94 mg/l) than SS (63.39 mg/l). The maximum values were recorded during summer (146.8 mg/l in RS and 102.2 mg/l in SS) which had a decreasing trend in monsoon and reaching lowest values in winter (75.2 mg/l in RS and 49.2 mg/l in SS). This observation is in concurrence with those of Gulati (1964), Singh (1965), Mehra (1986), Pathak and Shastree (1993). During winter, decomposition of organic matter gets reduced and CO_2 are not liberated into the aquatic medium. The latter is further deprived of its free CO_2 content due to high rate of photosynthesis by plants during clear days of winter. As a result, bicarbonates tend to dissociate to provide CO_2 and carbonates to the medium. Carbonates form salts with calcium which are insoluble and add to hardness of water. However, during summer rate of decomposition of organic matter increases. The free CO_2 which is liberated during decomposition, saturates water and prevents dissociation of bicarbonates into carbonates and as such CO_2 decreasing the hardness (Kaur *et al.*, 1995).

Total Dissolved Solid (TDS)

It is an aggregated amount of entire floating, suspended, settleable and dissolved solids present in water sample. Maximum value appeared in summer (312.5 mg/l in RS and 214 mg/l in SS) whereas minimum value observed in winter (121.5 mg/l in RS and 179 mg/l in SS). This observation is very much similar to the findings of Sinha *et al.* (1994). The appearance of maximum value in summer was due to evaporation and increase in particle concentration. Solids, above 350 mg/l have been accounted for adversely affecting the aquatic life and lethal expressions are expected (Verma *et al.*, 1975). The observed values for both the lakes were under critical limit that was further confirmed by fairly good growth of organism as observed by Pathak and Shastree (1993).

Turbidity (Tur)

Lowest values of turbidity were recorded in premonsoon period such as in the month of March in RS (9.5 NTU) and February in SS (8.0 NTU). Highest values appeared during monsoon months (43 NTU in RS and 35 NTU in SS). This may be due to greater inflow of muddy rainwater from the surrounding catchment area. This observation is in accordance with the view of Ajmal and Razi-ud-din (1988).

Chloride (Cl)

It's value ranged from 23-76.8 mg/l in RS and 20.2–69.0 mg/l in SS. Premonsoon showed highest values when water level was low followed by monsoon and postmonsoon with high water levels. Such condition also observed by Jana (1973) and Swarnalatha and Rao (1998) who found the rise of chlorides due to increased summer temperature and evapo-transpiration. The average values was higher in RS (52.50 mg/l) than SS (39.19 mg/l) due to higher human interferences/activities. Pollution through human faeces, domestic sewage and bathing increases chloride concentration results in eutrophication (Das and Sinha, 1994).

Phosphate (PO₄)

Maximum in monsoon of July (1.20 mg/l in RS and 1.05 mg/l in SS), minimum in premonsoon (0.03 mg/l in RS and 0.01 mg/l in SS), and higher in RS (0.41 mg/l) than SS (0.31 mg/l). Monsoon season had higher phosphate content due to phosphorous adsorption and inflow through the runoff water (Gainey and Lord, 1952). Higher phosphate content in RS may be due to decomposition of decaying leaves, bathing, washing as well as detergenic input.

Nitrite (NO₂)

Low in March (0.03 mg/l) in both the lakes and high during September in RS (0.49 mg/l) and August in SS (0.21 mg/l). Higher average values in RS (0.16 mg/l) than SS (0.10 mg/l) showed higher trophic status of RS.

Nitrate (NO₃)

It was higher in winter (1.10 mg/l RS and 0.88 mg/l in SS) and lower in summer (0.30 mg/l RS and 0.22 mg/l in SS). Munawar (1970), Hutchinson (1967) observed similar trend and suggested that in summer, denitrifying bacteria break up nitrates into nitrites and ammonia. In winter, however, the activity of these bacteria goes down (Kaur *et al.*, 1995), resulting in higher nitrate value in winter in these two lakes. Interestingly nitrate and dissolved oxygen show similar trends of fluctuation. This type of relationship also observed by Rao (1970) and Swarnalatha and Rao (1998).

Ammonium (Amon)

Ammonia present in the aquatic ecosystem mainly as the dissociated ion ammonium (NH₄⁺). Highest value showed during monsoon (0.57 mg/l in RS and 0.62 mg/l in SS) and lowest during winter (0.08 mg/l in RS and 0.01 mg/l in SS) appears to be inversely related to the macrophytic density.

In general, nutrients like PO₄, NO₂, NH₄⁺ were high during monsoon due to influx of nutrients from the surrounding upland areas/catchment area and high decomposition rate. Comparatively higher nutrient content in RS than SS signifies its eutrophication/higher trophic level.

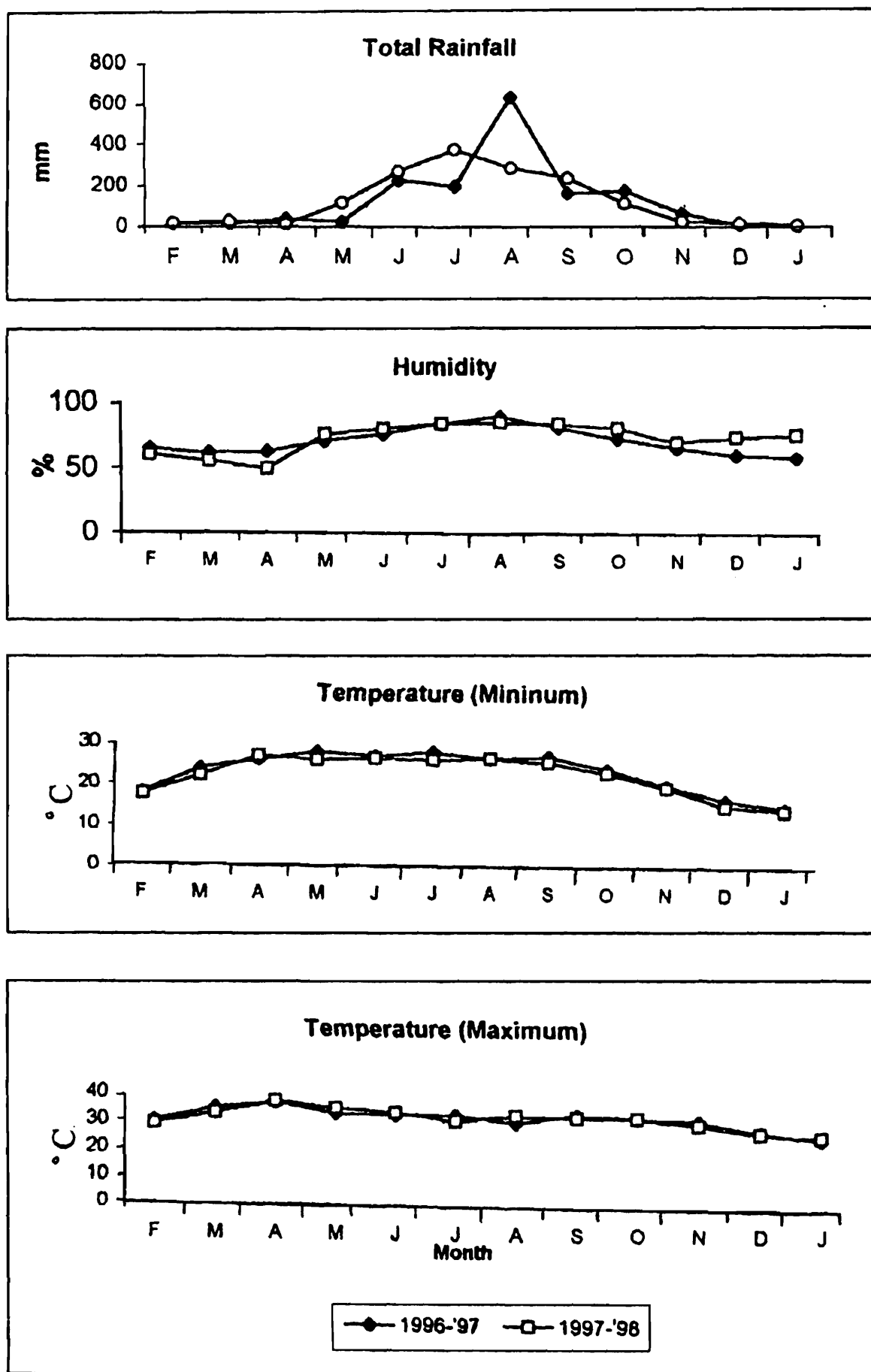


Fig. 3. Graph showing climatological condition of the study area.

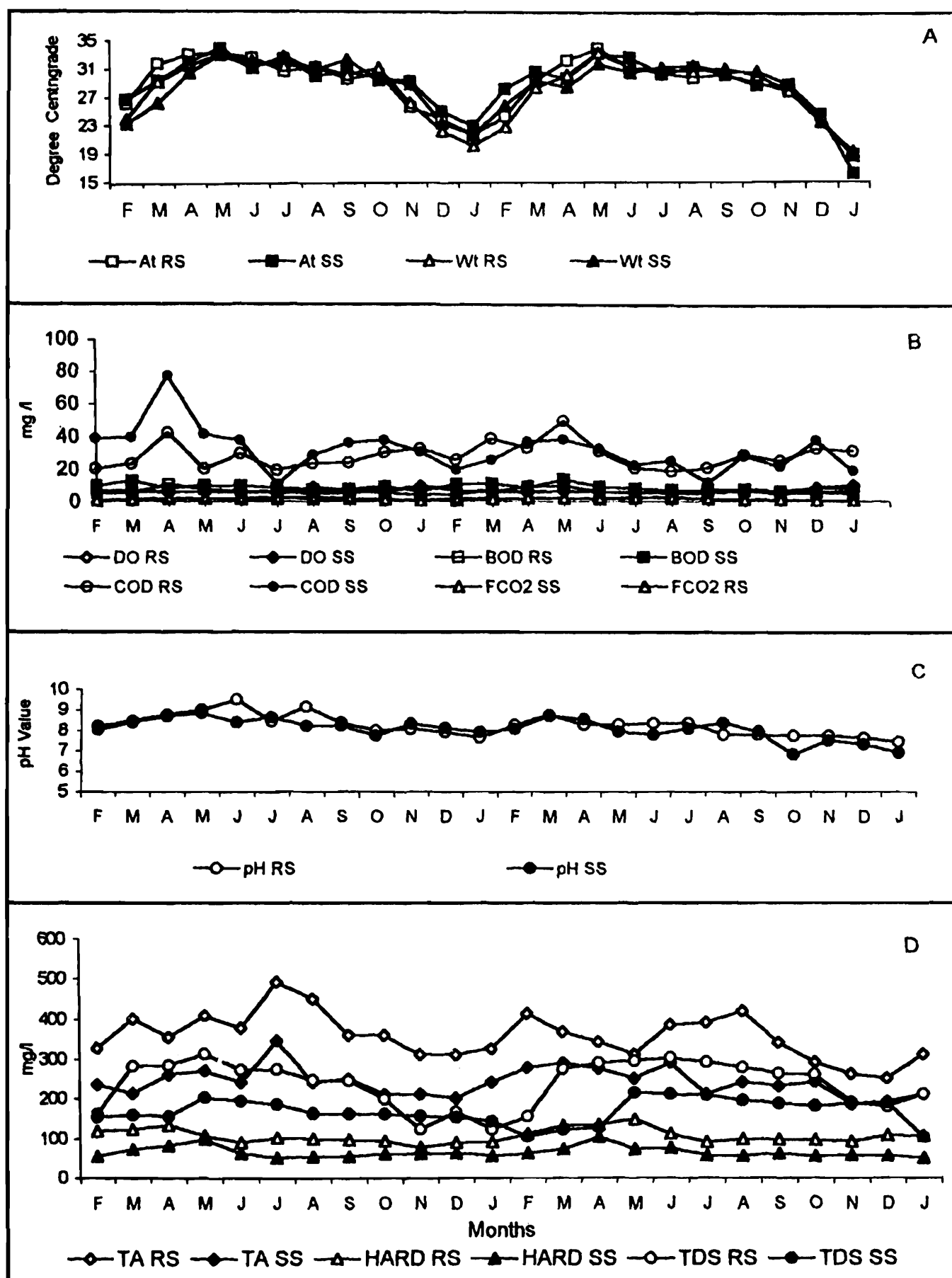


Fig. 4(A-D). Monthly variation of different physicochemical parameters of Rabindra Sarovar and Subhas Sarovar.

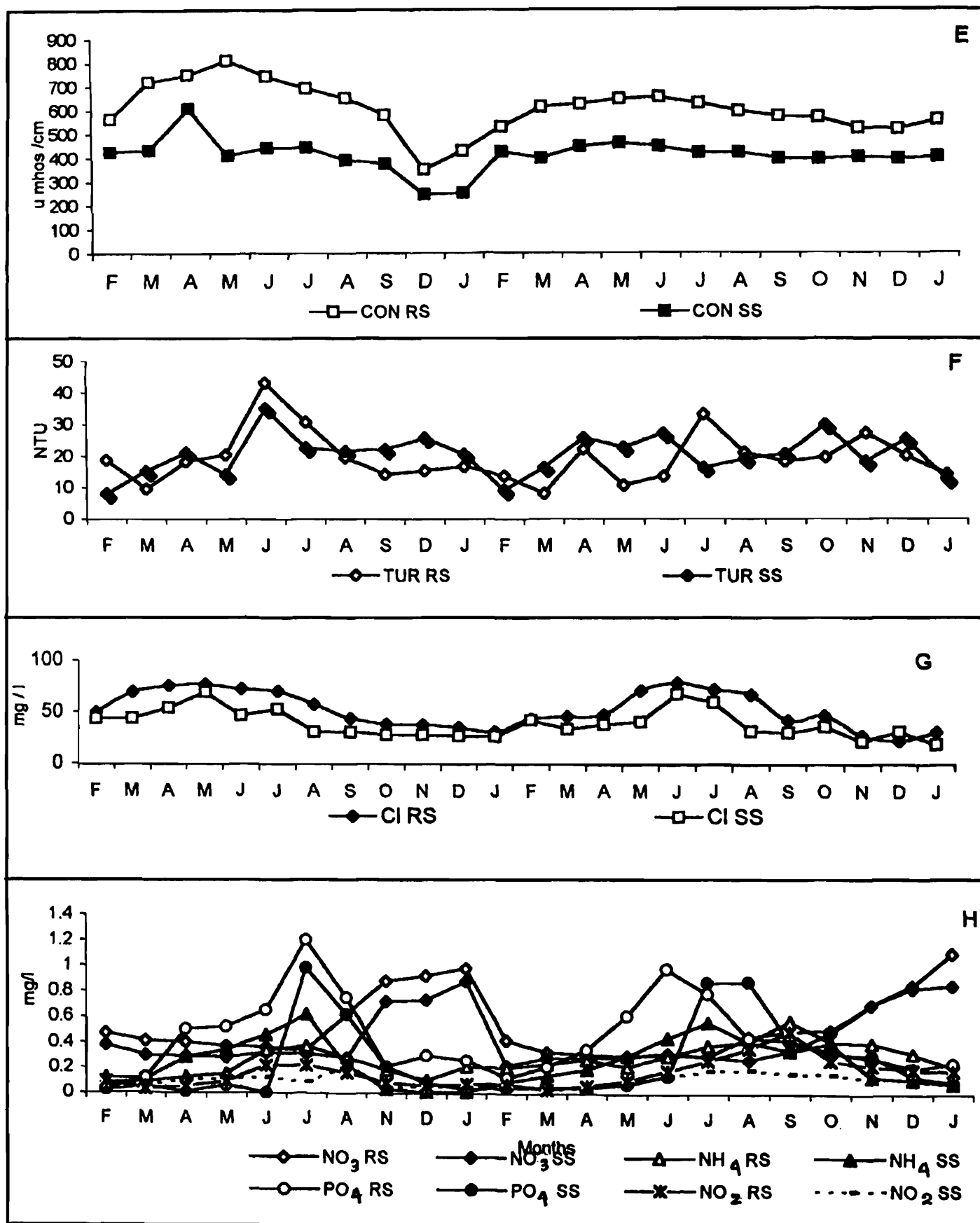


Fig. 4(E-H). Monthly variation of different physicochemical parameters of Rabindra Sarovar and Subhas Sarovar.

Table 1. Physicochemical characteristics of Rabindra Sarovar and Subhas Sarovar

PHYSICO CHEMICAL PARAMETERS	RABINDRA SAROVAR		SUBHAS SAROVAR	
	RANGE	MEAN $\pm$ SD	RANGE	MEAN $\pm$ SD
Air temperature (°C)	18.83-33.66	28.62 $\pm$ 3.85	16.2-33.93	28.93 $\pm$ 3.75
Water temperature (°C)	19.2-33.1	28.29 $\pm$ 4.08	18.67-32.93	28.31 $\pm$ 3.73
Dissolved oxygen (mg/l)	5.1-9.98	6.85 $\pm$ 1.23	4.81 – 8.94	6.26 $\pm$ 1.12
BOD (mg/l)	4.0-10.5	6.04 $\pm$ 1.63	5.5 – 13.5	8.33 $\pm$ 2.14
COD (mg/l)	18.5-49.1	28.33 $\pm$ 7.42	11.5-77.5	32.14 $\pm$ 12.96
Free CO ₂ (mg/l)	0.05-2.6	1.27 $\pm$ 0.67	0.25-2.80	1.35 $\pm$ 0.68
pH	7.41-9.48	8.23 $\pm$ 0.51	6.81-8.83	8.04 $\pm$ 0.52
Total alkalinity (mg/l)	250-493	356.42 $\pm$ 56.9	185-345	241.67 $\pm$ 36.3
Conductivity (μ mhos/cm)	311.5-805	583.54 $\pm$ 114.63	243-605	401.24 $\pm$ 65.9
CaCO ₃ Hardness (mg/l)	75.2-146.8	104.94 $\pm$ 17.42	49.2-102.2	63.39 $\pm$ 13.69
Total dissolved solid (mg/l)	121.5-312.5	235.83 $\pm$ 58.56	179-214	166.27 $\pm$ 31.15
Turbidity (NTU)	9.5-43.0	19.04 $\pm$ 7.96	8.0-35.0	19.84 $\pm$ 6.27
Chloride (mg/l)	23.0-76.8	52.50 $\pm$ 17.24	20.2-69.0	39.19 $\pm$ 13.23
Phosphate (mg/l)	0.03-1.20	0.41 $\pm$ 0.28	0.01-1.05	0.31 $\pm$ 0.33
Nitrite (mg/l)	0.03-0.49	0.16 $\pm$ 0.11	0.03 – 0.21	0.10 $\pm$ 0.05
Nitrate (mg/l)	0.30 – 1.10	0.54 $\pm$ 0.23	0.22-0.88	0.43 $\pm$ 0.21
Ammonium (mg/l)	0.08-0.57	0.26 $\pm$ 0.12	0.01 – 0.62	0.24 $\pm$ 0.17

4.3. Biotic Composition

4.3.1. Macrophyte

The aquatic macrophyte species recorded during study period are listed in Table 2. These macrophytes are represented by 23 species belonging to 16 plant families and 20 plant genera. Macrophytes are broadly divided under four categories *viz.*, free floating, submerged, emergent and marginal, each represented by seven, four, eight and four species respectively. Out of the total 23 species, 21 species were recorded from RS whereas 17 species from SS and of these 15 species were found common in both (Plates 1 and 2).

4.3.2. Macrofauna

Qualitative study reveals the presence of 4 major phyla represented by a total of 107 species under 54 families and 87 genera (Table 3; Plates 3 and 4).

Phylum Annelida includes Oligocheta represented by 2 species belonging to 1 family and 2 genera and Hirudinea represented by 3 species under 2 families and 3 genera.

Table 2. Occurrence of macrophytes in Rabindra Sarovar and Subhas Sarovar

Macrophyte Species	Rabindra Sarovar	Subhas Sarovar
A. FREE FLOATING (7 species)		
Family ARACEAE		
1. <i>Pistia sativa</i>	+	+
2. <i>Pistia stratiotes</i>	+	+
Family CONVULVACEAE		
3. <i>Ipomea aquatica</i>	+	+
Family LEMNACEAE		
4. <i>Lemna minor</i>	+	+
5. <i>Spirodella polyrrhiza</i>	+	+
Family PONTEDERIACEAE		
6. <i>Eichhornia crassipes</i>	+	+
Family SALVINIACEAE		
7. <i>Azolla filiculoides</i>	+	+
B. SUBMERGED (4 species)		
a) <i>Rooted to the bottom</i>		
Family HYDROCHARITACEAE		
1. <i>Blyxa octandra</i>	—	+
2. <i>Hydrilla verticillata</i>	+	+
3. <i>Vallisneria spiralis</i>	+	+
b) <i>Not rooted to the bottom</i>		
Family CERATOPHYLLACEAE		
4. <i>Ceratophyllum demersum</i>	+	—
C. EMERGENT (8 species)		
Family ALISMATACEAE		
1. <i>Sagittaria sagittifolia</i>	+	+
Family AMARANTHACEAE		
2. <i>Alternanthera paronychioides</i>	+	—
3. <i>Alternanthera philoxeroides</i>	+	+
4. <i>Alternanthera sessilis</i>	+	—
Family COMMELINACEAE		
5. <i>Commelina benghalensis</i>	+	—
Family GRAMINAE		
6. <i>Panicum</i> sp.	+	—
7. <i>Paspalum paspaloides</i>	+	+

Table 2. Contd.

Macrophyte Species	Rabindra Sarovar	Subhas Sarovar
Family NELUMBONACEAE		
8. <i>Nelumbo nucifera</i>	+	—
D. MARGINAL (4 species)		
Family COMPOSITAE		
1. <i>Mikania scandens</i>	—	+
Family CYPERACEAE		
2. <i>Cyperus</i> sp.	+	+
Family MARSILEACEAE		
3. <i>Marsilea minuta</i>	+	+
Family ONAGRACEAE		
4. <i>Ludwigia adscedens</i> (= <i>Jussiaea repens</i>)	+	+
Total (23 Species)	21 Species	17 Species

Phylum Arthropoda includes Crustacea represented by 7 species under 6 families and 6 genera; Insecta by 52 species under 5 orders, 19 families and 40 genera and Arachnida by 13 species under 6 families and 10 genera.

Phylum Mollusca includes Gastropoda represented by 14 species under 6 families and 9 genera and Bivalvia by 4 species under 2 families and 3 genera.

Phylum Chordata includes Pisces which is represented by weed fishes (class: Osteichthyes) comprising of 12 species under 11 families and 12 genera.

As a whole RS and SS are almost equally rich in species diversity, possessing 94 and 91 species respectively with 79 species of macrofauna common in both.

4.4. Macrophyte–Macrofaunal Association

To find out the diversity of macrofaunal community associated with macrophytes, six macrophyte species were selected, 2 each from comparatively abundant, floating and submerged categories whereas 1 each from sparsely distributed emergent and marginal categories.

Eighty macrofaunal species were found to be associated with six selected macrophyte species. The macrofaunal elements collected from each of these six macrophyte species are listed in Table 4. It is evident from the Table 4 that the highest number of macrofaunal species (53 species) was associated with *Ceratophyllum demersum*, a submerged plant with dissected leaf surface and the lowest 16 species occurred in *Alternanthera philoxeroides*, an emergent plant. This shows the general tendency that the greater the fragmentation of macrophyte leaves, the higher the taxonomical variability of the associated organisms.

Table 3. Occurrence of the macrofaunal species associated with macrophytes in Rabindra Sarovar and Subhas Sarovar

Macrofaunal Species	Rabindra Sarovar	Subhas Sarovar
I. ANNELIDA		
A. OLIGOCHAETA (2 species)		
Family TUBIFICIDAE		
1. <i>Branchiura sowerbyi</i> Bedd.	+	+
2. <i>Limnodrilus hoffmeisteri</i> Claparede	+	+
B. HIRUDINEA (3 species)		
Family GLOSSOPHONIDAE		
1. <i>Hemiclepsis marginata asiatica</i> Moore	+	+
2. <i>Placobdella emydae</i> Harding	-	+
Family HIRUDIDAE		
1. <i>Hirudinaria manillensis</i> (Lesson)	+	+
II. ARTHROPODA		
A. CRUSTACEA (7 species)		
Order Decapoda		
Family ATYIDAE		
1. <i>Caridina</i> sp.	+	+
Family GRAPSIDAE		
2. <i>Varuna litterata</i> (Fabr.)		+
Family PALAEMONIDAE		
3. <i>Macrobrachium dayanum</i> (Henderson)	+	+
4. <i>Macrobrachium lamarrei</i> (H. M. Edw.)	+	+
Family POTAMONIDAE		
5. <i>Sartoriana spinigera</i> (Wood-Mason)	-	+
Order ISOPODA		
6. Undetermined species	+	+
Order AMPHIPODA		
7. Undetermined species	-	+
B. INSECTA (52 Species)		
Order EPHEMEROPTERA (1 species)		
Family BAETIDAE		
1. <i>Cloeon kimminsi</i> Hubbard	+	+
Order ODONATA (9 species)		
Family LIBELLULIDAE		
1. <i>Brachythemis contaminata</i> (Fabr.)	+	+

Table 3. Contd.

Macrofaunal Species	Rabindra Sarovar	Subhas Sarovar
2. <i>Crocothemis servilia</i> (Drury)	+	+
3. <i>Orthetrum sabina</i> (Drury)	-	+
Family COENAGRIONIDAE		
4. <i>Agriocnemis pygmaea</i> (Rambur)	-	+
5. <i>Ceragrion coromandelianum</i> (Fabr.)	+	+
6. <i>Ischnura aurora</i> Brauer	+	+
7. <i>Ischnura senegalensis</i> (Rambur)	+	+
8. <i>Pseudagrion microcephallum</i> (Rambur)	+	+
Family GOMPHIDAE		
Order HEMIPTERA (18 species)		
Family BELOSTOMIDAE		
1. <i>Diplonychus annulatus</i> (Fabricius)	+	+
2. <i>Diplonychus rusticus</i> (Fabricius)	+	+
3. <i>Diplonychus</i> sp.	+	-
Family CORIXIDAE		
4. <i>Micronecta scutellaris</i> (Stal)	+	+
5. <i>Micronecta</i> sp.	-	+
Family GERRIDAE		
6. <i>Gerris adeloidis</i> Dohrn	+	
7. <i>Gerris spinolae</i> Lethierry and Severin	+	+
8. <i>Limnogonus nitidus</i> (Mayr)	+	+
9. <i>Limnogonus parvulus</i> (Stal)	+	
Family HYDROMETRIDAE		
10. <i>Hydrometra greeni</i> Kirkaldy	+	+
11. <i>Hydrometra</i> sp.	+	+
Family NEPIDAE		
12. <i>Laccotrephes griseus</i> (Guerin)	+	+
13. <i>Ranatra sordidula</i> Dohrn	+	+
14. <i>Ranatra filiformis</i> Fabricius	-	+
Family NOTONECTIDAE		
15. <i>Anisops breddini</i> Kirkaldy	+	+
16. <i>Anisops bouvieri</i> Kirkaldy	+	+
Family PLEIDAE		
17. <i>Plea liturata</i> (Fieber)	+	+
18. <i>Plea</i> sp.	+	+

Table 3. Contd.

Macrofaunal Species	Rabindra Sarovar	Subhas Sarovar
Order COLEOPTERA (20 species)		
Family CHRYSOMELIDAE		
1. <i>Cassida</i> sp.	+	+
2. <i>Dicladyspa armigera</i> (Oliv)		+
Family DYTISCIDAE		
3. <i>Canthydrus laetabilis</i> (Walker)	+	+
4. <i>Canthydrus luctuosus</i> Mots.	+	-
5. <i>Clypeodytes</i> sp.		+
6. <i>Hydrocoptus subvittulus</i> Mots.	+	+
7. <i>Hydrovatus</i> sp.	+	+
8. <i>Hydaticus fabricii</i> MacLeay	+	
9. <i>Laccophilus parvulus</i> Sharp	+	+
10. <i>Laccophilus sharpi</i> Reg.	+	+
11. <i>Uvarus quadrilineatus</i> (Zimm.)	+	+
Family HALIPLDAE		
12. <i>Haliplus</i> sp.	+	+
Family HYDROPHILIDAE		
13. <i>Amphiops pedestris</i> Sharp	+	+
14. <i>Berosus indicus</i> Mots.	+	+
15. <i>Enocrus</i> sp.	+	+
16. <i>Helochares anchoralis</i> Sharp	+	+
17. <i>Hydrophilus olivaceus</i> (Fabr.)	+	-
18. <i>Regimbertia attenuata</i> (Fabr.)	+	+
19. <i>Sternolophus rufipes</i> (Fabr.)	+	+
Family GYRINIDAE		
20. <i>Dineutus unidentatus</i> (Aube)	+	+
Order DIPTERA (4 species)		
Family CHIRONOMIDAE		
1. <i>Chironomus</i> sp.	+	+
Family CULICIDAE		
2. <i>Anopheles</i> sp.	+	+
3. <i>Culex</i> sp.	+	+
Family STRATIOMYIDAE		
4. <i>Odontomyia dorsoangulata</i> Brunetti	+	+

Table 3. Contd.

Macrofaunal Species	Rabindra Sarovar	Subhas Sarovar
C. ARACHNIDA (13 species)		
Order ARANEAE		
Family ARANEIDAE		
1. <i>Larinia</i> sp.	+	
Family LYCOSIDAE		
2. <i>Evipa shivaji</i> Tikader and Malhotra	+	
3. <i>Lycosa</i> sp.	+	+
4. <i>Pardosa alii</i> Tikader	+	+
5. <i>Pardosa annandalei</i> (Gravely)	+	+
6. <i>Pardosa birmanica</i> Simon	+	+
7. <i>Pardosa pusiota</i> (Thorell)	+	+
Family SALTICIDAE		
8. <i>Salticus</i> sp.	+	
9. <i>Myrmarchne</i> sp.	+	
Family TETRAGNATHIDAE		
10. <i>Tetragnatha</i> sp.	+	+
Family THERIDAE		
11. <i>Theridion</i> sp.	-	+
Order ACARINA		
12. <i>Arrenurus</i> sp.	+	
13. <i>Unionicola</i> sp.	+	
III. MOLLUSCA		
A. GASTROPODA (14 species)		
Family BITHYNIIDAE		
1. <i>Digoniostoma cerameopoma</i> (Benson)	+	+
2. <i>Gabbia orcula</i> (Nevill)	+	+
Family LYMNAEIDAE		
3. <i>Lymnaea accuminata</i> (Lamarck)	+	+
4. <i>Lymnaea luteola</i> (Lamarck)	+	+
Family PILIDAE		
5. <i>Pila globosa</i> (Swainson)	+	+
Family PLANORBIDAE		
6. <i>Gyraulus convexusculus</i> (Hutton)	+	+
7. <i>Gyraulus labiatus</i> (Benson)	+	+
8. <i>Indoplanorbis exustus</i> (Deshayes)	+	+
Family THIARIDAE		
9. <i>Brotia costula</i> (Rafinesque)	+	+
10. <i>Thiara granifera</i> (Lamarck)	+	+

Table 3. Contd.

Macrofaunal Species	Rabindra Sarovar	Subhas Sarovar
11. <i>Thiara lineata</i> (Gray)	+	+
12. <i>Thiara scabra</i> (Mueller)	+	+
13. <i>Thiara tuberculata</i> (Mueller)	+	+
Family VIVIPARIDAE		
14. <i>Bellamya bengalensis</i> (Lamarck)	+	+
B. BIVALVIA (4 species)		
Family PISIDIIDAE		
1. <i>Pisidium clarkeanum</i> G and H Nevill	+	+
Family UNIONIDAE		
2. <i>Lamellidens corrianus</i> (Lea)	+	-
3. <i>Lamellidens marginalis</i> (Lamarck)	+	+
4. <i>Parreysia caerulea</i> (Lea)	+	-
IV. PISCES		
A. OSTEICHTHYES (12 species)		
Family BELONIDAE		
1. <i>Xenentodon cancila</i> Ham.	+	-
Family BELONTIDAE		
2. <i>Colisa fasciata</i> (Schn.)		+
Family CHANDIDAE		
3. <i>Ambassis nalu</i> (Ham.)	+	+
4. <i>Chanda ranga</i> (Ham.)	+	+
Family CHANNIDAE		
5. <i>Channa striatus</i> (Blotch)	+	+
Family CICHLIDAE		
6. <i>Oreochromis nilotica</i> Val.	+	+
Family CYPRINIDAE		
7. <i>Aplocheilichthys panchax</i> (Ham.)	+	+
Family CYPRINODONTIDAE		
8. <i>Puntius phutunio</i> (Ham.)	+	+
Family GOBIDAE		
9. <i>Glossogobius giuris</i> (Ham.)	+	+
Family MASTACEMBELIDAE		
10. <i>Mastacembelus pancalus</i> (Ham.)	-	+
Family NANIDAE		
11. <i>Badis badis</i> (Ham)	+	+
Family SYMBRUNCHIDAE		
12. <i>Amphiprion cuchia</i> (Ham.)	+	+
TOTAL (107 species)	94 species	91 species

Table 4. Macrofaunal association with six selected species of macrophytes

MACROFAUNAL GROUP	Macrofaunal species associated with different categories/species of macrophytes					
	FLOATING		SUMERGED		EMERGENT	MARGINAL
	<i>Eichhornia crassipes</i>	<i>Pistia sativia</i>	<i>Ceratophyllum demersum</i>	<i>Vallisneria spiralis</i>	<i>Alternant-hera philoxerodides</i>	<i>Ludwigia adscedens*</i>
OLIGOCHAETA	2 (Bs,Lh)		2(Bs,Lh)	2(Bs,Lh)		
HIRUDINEA		1 (Hma)	2 (Pe,Hma)	1 (Hma)	1 (Hma)	
CRUSTACEA	5(Ca,Isopod, Md,Ml,Ss)	1 (Md)	5(Amphipod, Ca, I sopod, Md, MI)	4 (Isopod, (Md, MI, Ss)	3(Isopod, Md, MI)	3 (Isopod, Md, MI)
ARACHNIDA	3(Pa, Pb, Pp)	4(Pa,Pb,Ts)				1(pa)
EPHEMEROPTERA	1(Ck)		1 (Ck)	1 (Ck)	1(Ck)	1(Ck)
ODONATA	4(Bc,Is,Pm,Os)	3(Bc,Is,Pm)	6(Bc,Cc,Ia,Ir, Is, Pm)	4(Bc,Ia,Is, Pm)	3(Ap,Ir,Pm)	
HEMIPTERA	7(Ab,Da,Dr,Lp, Ms,Ps,Rs)	6(Ab,Da,Dr,Lg Ps,Rs)	8 (Ab,Da,Dr,Hg, Ms,Pl,Rf,Rs)	8 (Ab,Ap,Da, Dr,Gs,Lg, Ps,Rs)	4 (Da,Dr, Ps,Rs)	5 (Ab,Da,Dr, Rf, Rs)
COLEOPTERA	9(Bi,Cl,Cls,Du, Es,Ha,Hs,Ra,Uq)	7(Ape,Cl,Cls, Du,Hs,Lip,Uq)	7(Cl,Du,Ha,Hs, Lip,Ls,Uq)	8(Ap,Bi,Ha, Ho,Hs,Lip, Sr,Uq)		7(Ap,Bi,Cl, Ha,Hs,Lip, Uq)
DIPTERA	3(As,Cs,Od)	1(Cs)	3(As,Cs,Od)	2(As,Cs)		
GASTROPODA	7(Bb,Brc,Gl,Go, Ie,Tg,Tt)	7(Bb,Brc,Gl,Go, Ie,Tg,Tt)	11(Bb,Brc,Dc, Gl,Go,Ie,Li,Tg, La, Tl)	11(Bb,Brc,Dc, Gl,Go,Ie,Ll, Tg,Tl,Ts,Tt)	3(Bb,Gl,Go)	6(Bb,Brc,Go, Ie,Tg, Tt)
BIVALVIA			2(Lm, Pc)	2(Lm,Pc)		
PISCES	2(An,On)		6(An,Bba,Cf, Cr,Gg,Pph)	7(Ac,An,Bba Cp,Gg, Mp,Pph)	1(Cst)	
TOTAL	43	30	53	50	16	23

Note : 1, *Synonym *Jussiaea repens*. 2. For macrofaunal species name *vide* list of abbreviation in pages 3-4 above.

(Kornijów and Gulati, 1992). It is also evident that among different categories of macrophytes, submerged vegetation is the most preferred macrophyte type for macrofaunal assemblage. The macrofaunal community inhabiting *Eichhornia crassipes* was characterised by relatively high number of coleopteran species (9 species) due to their bushy root and leaf surface offering shelter and spongy petiole as feeding ground and egg laying site. Like *Eichhornia*, *Pistia stratiotes* also preferred by coleopterans (7 species) and arachnids (4 species). Spiders are usually epineustonic form and hence were recorded from aerial parts of floating and marginal macrophytes. Both the submerged macrophytes, *Ceratophyllum demersum* and *Vallisneria spiralis* supporting maximum number of gastropod species (11 species) as they provide ample surface area for shelter as well as site for feeding, oviposition, development and hiding places. *Alternanthera philoxeroides* with their comparatively hard stem failed to support any coleopteran species whereas *Ludwigia adscedens* with their soft stem offers excellent cell sap/plant tissue for feeding by coleopterans as high as seven species.

4.5. Population Distribution

4.5.1. Macrophyte distribution in different stations

To find out the macrophyte distribution, macrophyte samples were collected at random from different site of each station and dry weight was taken. Total 40 samples were taken for each station seasonally. The percentages were calculated on the basis of dry weight of different category of macrophytes/square metre water area. The percentage frequency distributions of four categories of macrophytes of two lakes at different stations and in different seasons are presented in Figs. 5 and 6. It is evident from the Figures that the submerged macrophyte is the most dominant category over the other in both the lakes except in monsoon season (June–September) at RS when floating macrophytes dominate the plant diversity in the lakes concerned.

Among the three different stations, a higher percentage of submerged macrophytes and very negligible amount of floating macrophytes supported station 2 of RS. This may be due to the fact that the less amount of floating macrophytes facilitates penetration of sunrays resulting in luxuriant growth of submerged macrophytes. Sharma and Rai (1989) also observed inverse relationship between floating and submerged macrophytes. The percentage of submerged macrophytes is more or less equal during premonsoon (February–May) and postmonsoon (October–January) but considerably low during monsoon (June–September) in both the lakes as also observed by Sharma and Rai (1989) and Dey and Kar (1989). Emergent macrophyte contribute higher percentage during monsoon in both the lakes except at Station 3 of SS where postmonsoon shows higher percentage during 1997–'98. The marginal macrophytes also show almost the same trend of emergent macrophyte except at Station 2 of SS, which shows the higher percentage during postmonsoon.

The percentage distribution of different categories of macrophytes are not exactly similar in these two lakes at different seasons which may be due to differences in deweeding activity as well as physicochemical factors and human interference.

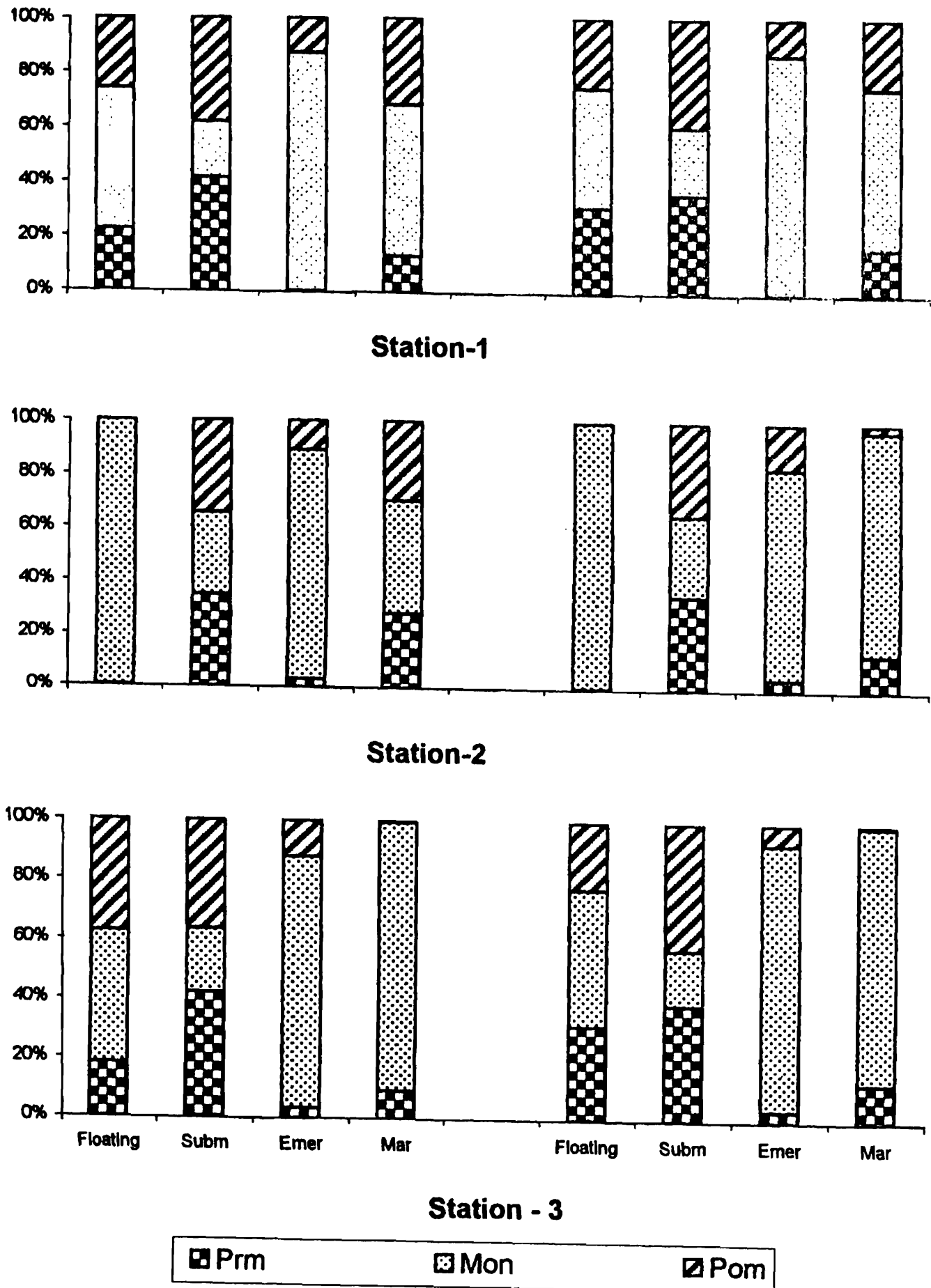


Fig. 5. Stationwise distribution of macrophyte in different seasons of Rabindra Sarovar.

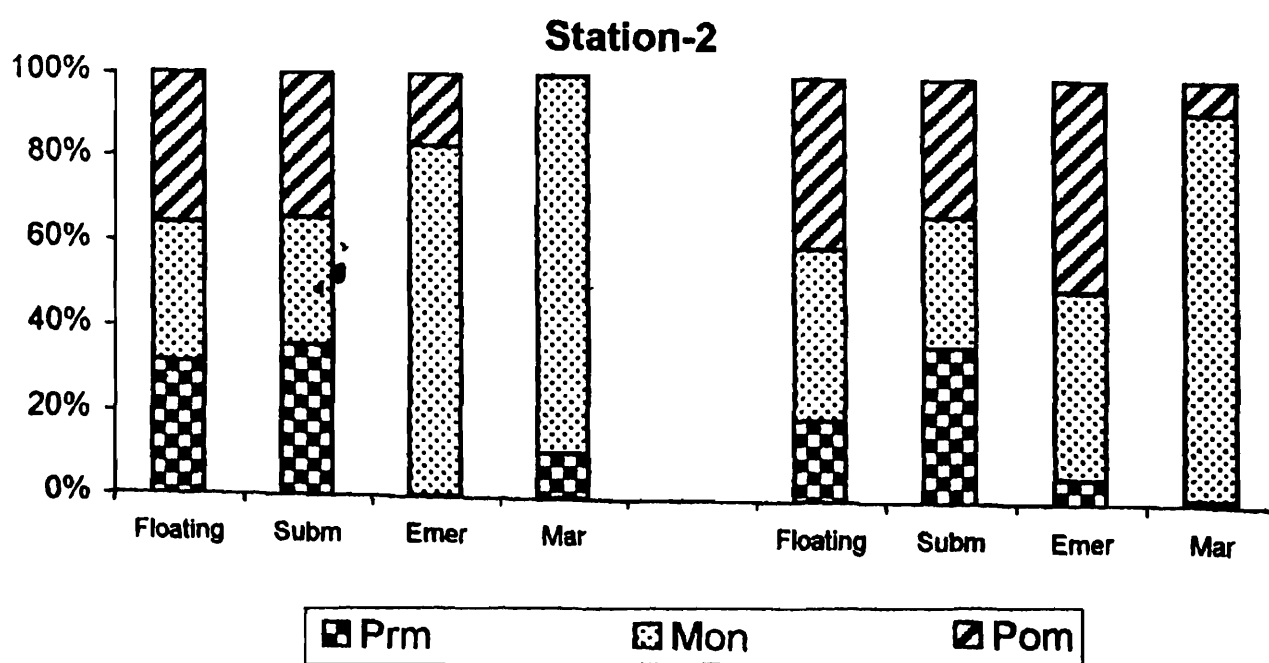
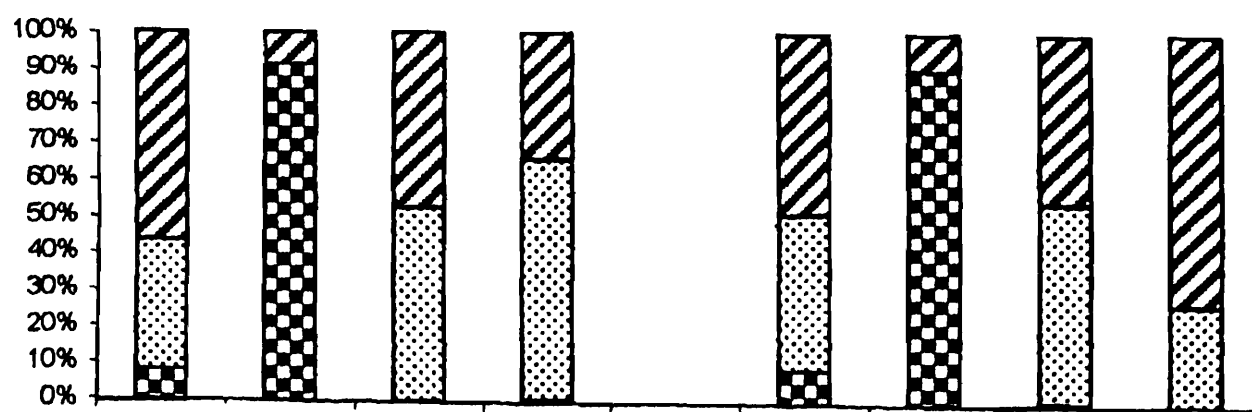
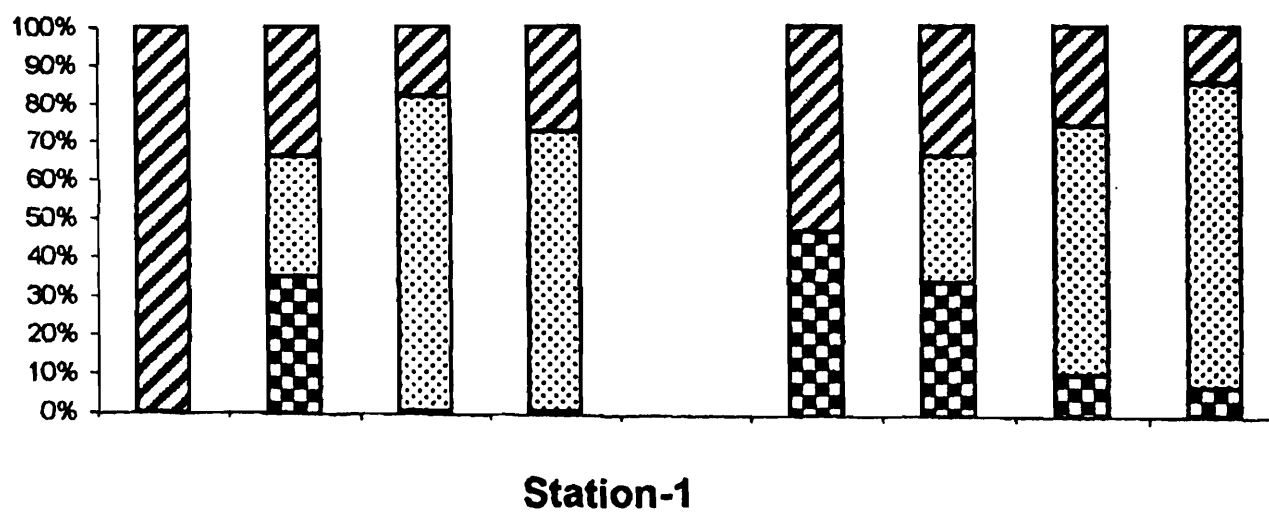


Fig. 6. Stationwise distribution of macrophyte in different seasons of Subhas Sarovar.

4.5.2. Macrofaunal distribution in different stations

Eight major macrofaunal groups that are usually associated with macrophytic vegetation were selected for this study. The percentage frequency distributions of these eight groups were calculated on the basis of total dry weight of the individuals of respective groups per square metre water area and presented in Figs. 7 and 8. It is evident that gastropods are the most dominant group followed by crustaceans and insects.

Among the different stations, Station 3 of RS and Station 1 of SS show comparatively higher percentage of gastropods in all the seasons whereas crustaceans at Station 2 of RS and Station 3 of SS show this type of dominance. The other macrofaunal groups, however, showed no such specific dominance pattern during the study period. The fluctuation in distribution pattern observed from year to year may be due to differences in the vegetational profile.

4.6. Macrofaunal Density in Six Selected Macrophytes

The densities of dominant macrofaunal groups per 100 gm of macrophyte wet weight on six different plant species are presented in Fig. 9. The most dominant macrofaunal group, Gastropoda as well as the total macrofauna were abundant on *Ceratophyllum* followed by *Vallisneria*. Higher macrofaunal density associated with submerged macrophytes was observed by several authors (Krecker, 1939; Harrod, 1964; Dvorak and Best, 1982). In case of crustaceans the higher density was observed on *Vallisneria* during premonsoon and monsoon months whereas during postmonsoonal period the preference is shifted to *Ceratophyllum*. Mechanical deweeding activity that increases during late monsoon period probably reduces the density of the rootless submerged macrophytes like *Ceratophyllum*. In the postmonsoon period existing crustacean population likely to be associated with remaining *Ceratophyllum* which ultimately increases the density. Insects' preference was slightly higher towards *Ludwigia* due to their soft stem, which serve as their feeding ground.

4.7. Population Fluctuation and Biomass Distribution of Major Macrofaunal Groups and Species

The macrofaunal community associated with macrophytes of RS and SS were comprised of twelve major macrofaunal groups viz., Oligochaeta, Hirudinea, Crustacea, Arachnida, Ephemeroptera, Odonata, Hemiptera, Coleoptera, Diptera, Gastropoda, Bivalvia and Pisces (Table 5). The population density and biomass distribution pattern of these groups are presented separately by histogram and line graph respectively in Fig. 10(A-N). The monthwise abundance for 20 regularly occurring species are shown in Tables 6 and 7.

Oligochaeta

The density of oligochaetes varied from 2.18/m² (January) to 48.33/m² (July) in RS and from 4.16/m² (May) to 142.35/m² (August) in SS. The population showed marked increase during monsoon, which declined considerably during premonsoon in both the

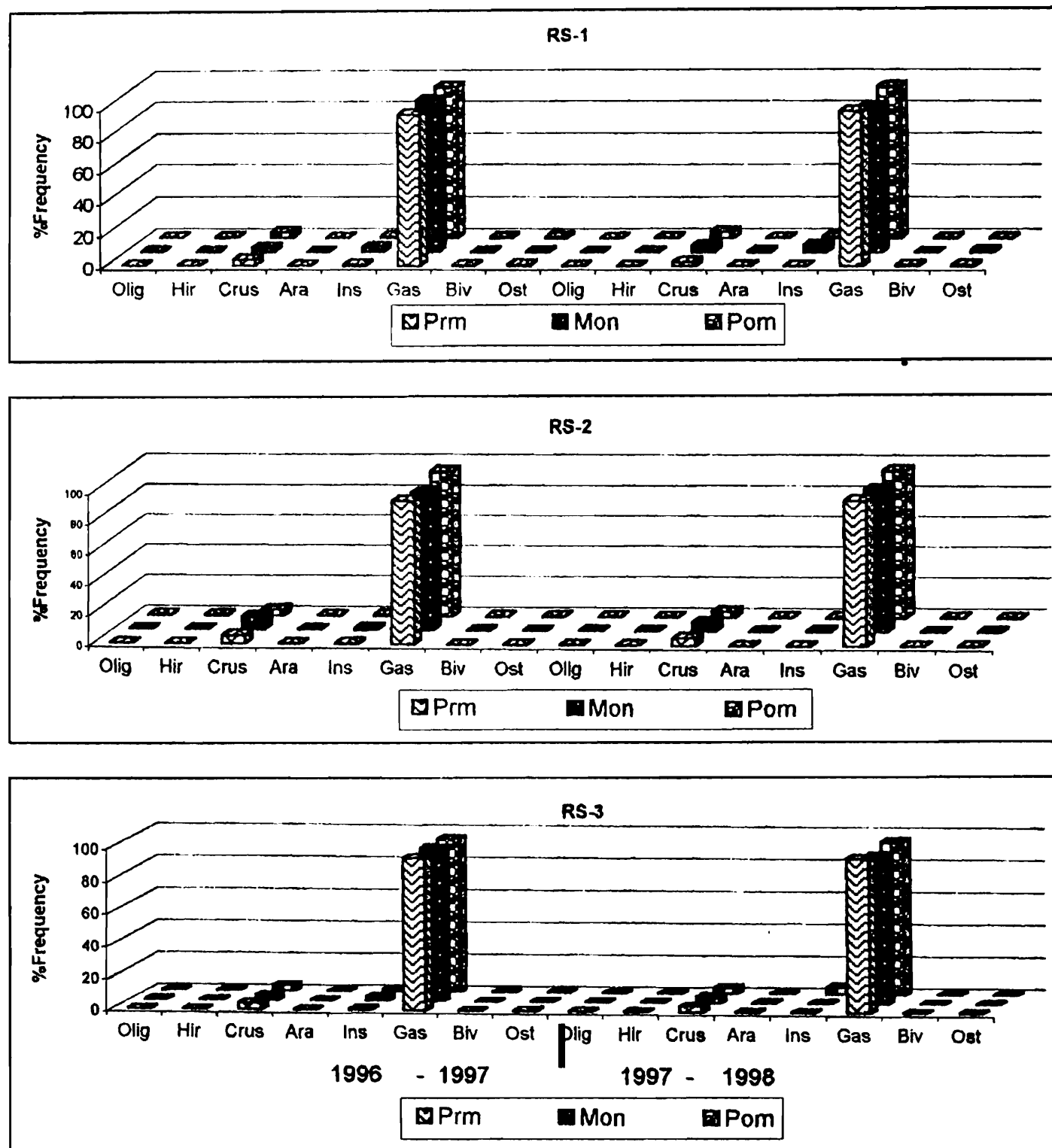


Fig. 7. Stationwise seasonal distribution of different macrofaunal groups in Rabindra Sarovar

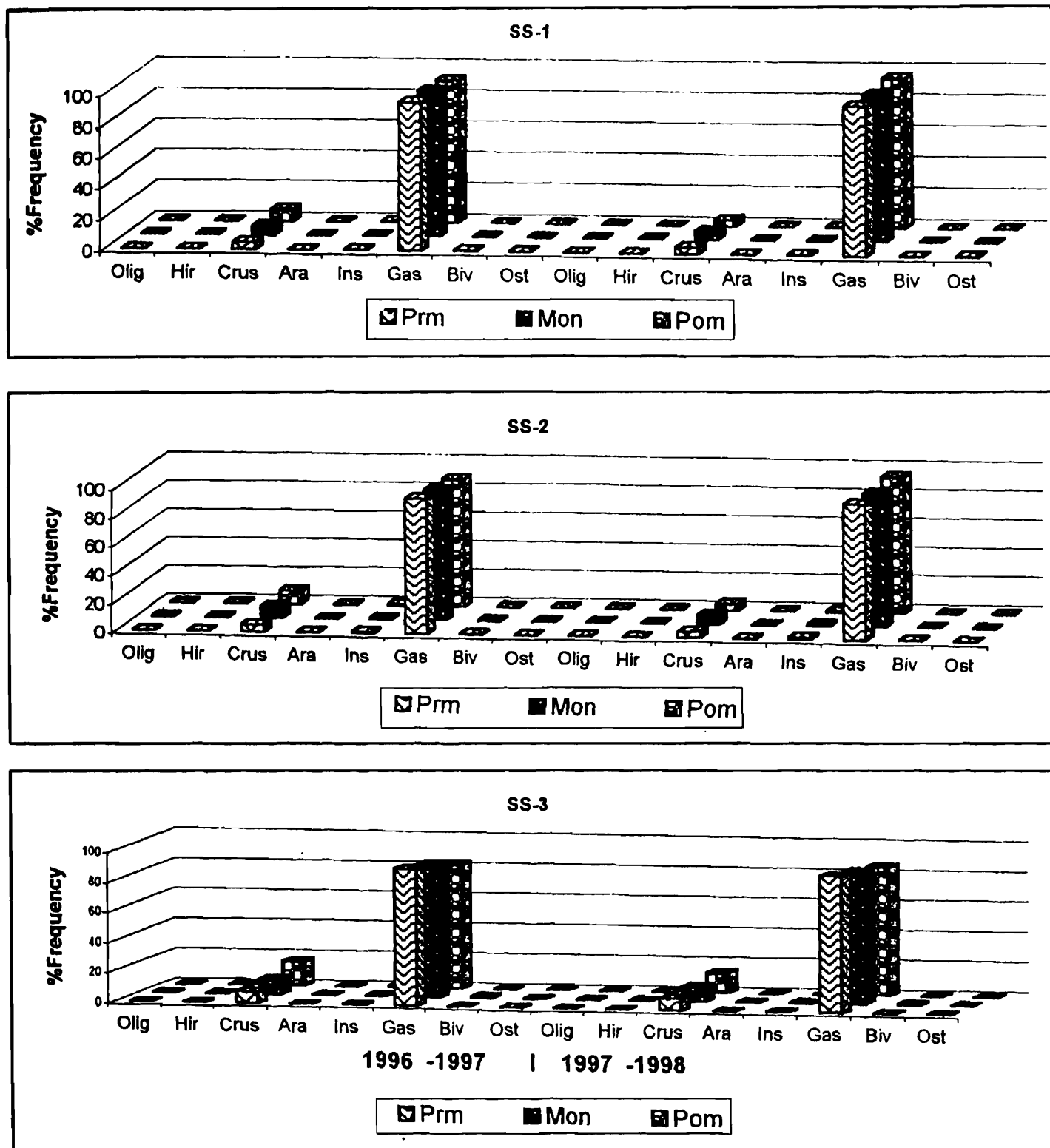


Fig. 8. Stationwise seasonal distribution of different macrofaunal groups in Subhas Sarovar.

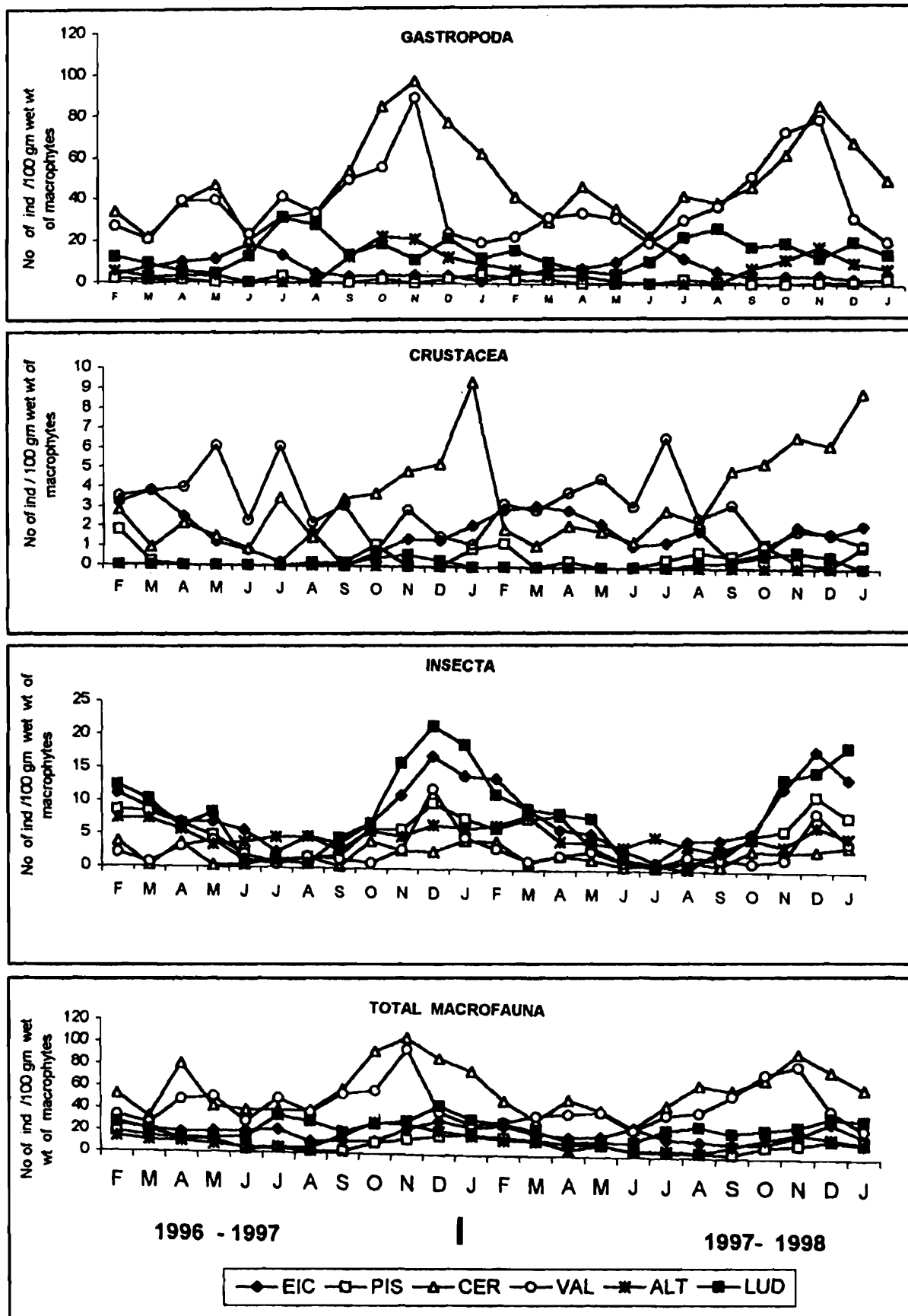


Fig. 9. Population density of dominant macrofaunal groups associated with six selected species of macrophytes.

lakes (Fig. 10A). Maximum density was observed in July in Rs and in August in SS for both the years. Biomass also followed the same pattern. In RS, the peak biomass was shown in December in 1996-'97 and in August during the 1997-'98. It is clearly evident from the Fig 10A and Table 5 both density and biomass of oligochaete population were higher in SS than RS. This may be due to the fact that SS possesses more suitable sediment as well as weed environment for the growth and abundance of oligochaete population.

In these two lakes, the group Oligochaeta was represented by a single dominant species *Limnodrilus hoffmeisteri*. The soft clay soil with decaying leaves and other organic matter influence oligochaete population (Subla, 1967). Brinkhurst (1966, 1974) and Mason *et al.* (1971) stated that *Limnodrilus hoffmeisteri* preferred littoral and sublittoral zones. Dominance of *Limnodrilus* sp. has been reported by several workers (Milbrink, 1973; Petridis and Sinis, 1993; Singh and Sinha, 1993; Bose and Lakra, 1994). David and Ray (1966) stated that oligochaetes increase with eutrophication and can survive in an environment where anaerobic/saprobic bacterial activity is intense. The occurrence of *Limnodrilus* sp. may be attributed to increased eutrophication of a lake or to the increased sedimentation of organic matter (Aston, 1973 and Marshall, 1978). During present investigation *Limnodrilus hoffmeisteri* was found in amongst weeds at littoral depth.

According to Jonasson (1969) tubificids are well adapted to low oxygen content as their blood is rich in haemoglobin. Mason (1981) and Cowell and Vodopich (1981) found an uniformity in the abundance of oligochaetes in all months of the year, while Mandal

Table 5. Biannual mean density and percentage frequency of different macrofaunal groups in Rabindra Sarovar and Subhas Sarovar

Macrofaunal Group	Mean Density (no/m ²)		Percentage Frequency (%)	
	Rabindra Sarovar	Subhas Sarovar	Rabindra Sarovar	Subhas Sarovar
OLIGOCHAETA	13.72	38.80	1.41	3.00
HIRUDINEA	1.13	12.75	0.08	0.99
CRUSTACEA	60.73	68.39	4.34	5.28
ARACHNIDA	5.24	3.09	0.37	0.24
EPHEMEROPTERA	1.78	3.02	0.13	0.24
ODONATA	14.85	15.73	1.06	1.21
HEMIPTERA	22.21	12.88	1.58	0.99
COLEOPTERA	3.25	15.96	0.23	1.23
DIPTERA	10.36	40.85	0.75	3.16
GASTROPODA	1249.98	1072.55	89.44	82.87
BIVALVIA	4.79	6.71	0.35	0.52
PISCES	3.71	3.47	0.26	0.27
TOTAL	1397.75	1294.20	100	100

Table 6. Temporal variation in density (no/m²) of different dominant macrofaunal species in RS

42

YEAR	MONTH	Dominant Macrofaunal Species																			
		Lh	MI	Md	Pm	Bc	Da	Dr	Ps	Rs	Hs	Chr	Bb	Go	Dc	Tg	Tt	BrC	Gl	Pc	Gg
1996	Feb	4.2	28.5	38.2	12.5	1.32	0.95	0.20	2.3	1.4	1.94	18.2	306.9	702.1	3.85	202.9	41.1	20.1	402.7	2.6	3.2
	Mar	4.8	22.5	36.2	4.2		0.24	0.12	1.1	2.4	1.9	12.4	192.4	905.5	4.2	323.9	66.3	12.2	520.3	3.1	4.1
	Apr	4.9	10.2	26.2	19.5	0.82	0.85	1.61	5.0	0.28	2.1	6.2	296.3	555.3	2.1	146.5	41.2	9.3	162.5	2.2	2.8
	May	7.1	5.9	18.3	7.2	7.3	0.91	2.1	7.3	1.2	2.1	3.1	302.6	106.9	3.7	85.2	28.7	12.3	89.5	1.2	1.3
	June	12.6	13.0	21.5	7.1	12.4	0.61	1.21	5.0	0.92	2.7	0.03	310.3	102.9	4.2	74.9	29.4	9.3	70.2		0.5
	July	31.2	18.5	29.6	10.3	7.2	2.3	0.82	0.42	1.0	3.8		155.6	40.5	6.5	41.3	11.1	7.1	12.2		0.1
	Aug	22.5	26.5	33.5	8.2	1.0	20.1	1.0	3.2	0.12	3.2	0.56	96.8	88.5	12.5	85.9	9.0	10.1	20.3		0.8
	Sep	8.5	20.3	51.0	4.2		1.7	0.24	0.81	0.02	5.6	1.9	258.5	220.3	30.0	146.5	26.4	41.0	102.5		1.1
1997	Oct	6.1	26.1	42.5	5.2	0.23	8.4	2.4	4.4	1.0	3.0	3.1	203.5	370.7	18.9	139.2	35.3	63.7	316.4		1.2
	Nov	4.2	24.2	33.6	6.2	2.3	10.1	3.4	4.9	2.1	2.0	11.2	585.6	280.3	20.5	162.3	52.9	74.4	512.3		0.9
	Dec	1.1	13.4	48.9	8.3		7.5	3.6	5.0	1.8	1.1	13.3	522.8	365.3	10.3	202.3	32.6	81.2	498.2	2.3	1.7
	Jan	1.9	13.1	78.5	20.6	4.3	3.3	5.2	6.3	1.5	0.98	54.2	386.5	492.4	2.7	145.6	41.6	61.2	458.6	5.2	2.2
1997	Feb	11.2	30.2	56.5	17.3	2.1	1.3	1.2	2.4	2.8	1.6	10.1	222.3	578.9	4.5	187.5	30.2	22.3	501.4	4.1	4.5
	Mar	14.2	8.8	28.4	6.2		0.52	0.41	2.0	1.0	1.9	9.5	188.6	621.3	10.4	105.5	59.3	23.9	532.4	14.6	2.6
	Apr	14.8	14.2	27.3	5.2	1.1	0.56	2.1	8.3	1.2	2.0	5.3	216.5	302.6	12.3	89.9	43.5	12.4	210.4	10.1	2.1
	May	20.3	8.7	20.1	3.2	0.98	0.61	1.8	6.1	0.62	2.3	4.6	204.6	220.3	14.9	91.7	57.0	15.4	102.3	6.6	1.4
	June	26.5	12.9	29.9	4.2	8.2	0.74	3.2	5.0	1.9	2.4		158.5	198.6	12.4	73.5	32.0	11.1	96.8	2.1	0.42
	July	30.0	12.3	26.2	6.1	7.0	12.2	1.1	0.85	1.1	4.0		63.5	31.7	10.5	42.3	13.5	6.7	11.3		0.3
	Aug	23.1	13.0	28.5	6.2		31.2	2.0	1.2	0.23	5.2		79.9	83.5	18.4	69.9	10.2	11.3	18.5		0.56
	Sep	12.2	15.1	32.1	4.2		7.2	1.2	1.3	0.9	4.3	1.0	102.2	118.2	28.3	44.3	18.0	9.1	50.2		0.9
1998	Oct	13.5	20.2	41.0	8.3	-	2.9	0.98	0.15	0.22	3.1	2.0	102.4	574.4	19.5	142.5	45.0	54.2	296.1		1.2
	Nov	10.5	29.2	52.0	10.5	4.1	4.3	3.9	5.2	2.2	2.4	6.3	370.7	422.5	22.3	170.5	42.0	82.2	427.2		0.86
	Dec	2.3	23.3	49.9	9.1	0.32	4.4	6.2	7.2	2.3	1.5	8.3	307.5	310.6	20.5	200.5	46.1	85.0	435.4		0.82
1998	Jan	6.2	27.5	86.2	10.2	0.98	3.0	7.2	7.0	2.5	0.8	30.3	414.2	402.5	3.5	186.8	40.0	53.5	415.3	6.7	0.8

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Table 7. Temporal variation in density (no/m²) of different dominant macrofaunal species in SS

YEAR	MONTH	Dominant Macrofaunal Species																			
		Lh	MI	Md	Pm	Bc	Da	Dr	Ps	Rs	Hs	Chr	Bb	Go	Dc	Tg	Tt	Brc	Gl	Pc	Gg
1996	Feb	12.2	33.1	81.0	.94	0.19	0.12	0.01	0.45	2.0	3.3	1221.1	780.2	110.2	11.1	41.3	10.3	21.3	51.9	1.29	1.2
	Mar	14.5	4.4	12.2	8.3	3.5	1.1	3.2	2.3	7.1	4.1	33.5	617.9	165.1	5.6	36.7	19.4	22.9	39.3		4.2
	Apr	13.2	20.6	21.5	12.4	5.2	0.98	1.4	10.1	2.8	31.4	14.4	824.4	130.5	3.5	47.5	21.2	27.5	36.1	18.2	3.7
	May	6.21	22.3	22.3	3.8	7.5	0.21	0.04	0.82	1.2	4.0	7.2	1092.3	310.5	2.5	65.5	38.4	66.3	38.1	1.3	0.34
	June	10.9	38.5	19.5	15.2	12.3	3.1	1.1	0.61	0.98	4.0	4.0	802.5	200.5	2.8	41.3	52.1	77.0	36.0	4.9	1.1
	July	53.5	28.4	13.5	10.2	0.84	3.3	0.62	0.12	0.10	5.0		514.4	116.4	1.7	28.3	47.1	84.9	20.1	8.9	0.12
	Aug	62.5	33.2	29.5	6.3	0.56	3.95	0.82	0.13	0.15	2.1		202.4	70.4	1.9	31.5	48.2	80.5	7.3	2.0	0.74
	Sep	38.5	40.9	42.3	4.2		18.2	3.1	3.5	0.25	3.4	3.2	255.2	62.45	20.3	35.0	19.5	78.5	5.3		2.3
	Oct	25.3	52.1	44.5			8.2	1.1	0.41	0.2	5.9	10.1	420.4	46.5	28.5	40.6	19.0	61.4	8.5		1.0
	Nov	18.6	41.4	52.5	2.1		7.1	1.0	3.5	0.84	2.0	3.1	319.1	26.5	29.1	50.2	25.6	52.2	12.4		4.8
1997	Dec	22.3	42.4	59.5	12.3	1.0	1.3	8.2	4.1	1.6	10.0	201.5	501.6	42.6	41.5	58.3	30.4	72.5	32.5	0.85	1.3
	Jan	11.2	70.0	66.5	20.0	0.05	1.1	9.5	5.3	1.8	12.2	288.9	492.4	61.8	26.5	36.0	26.2	48.9	46.7	1.9	1.3
	Feb	18.5	41.4	80.9	.3	0.02	0.25	0.32	1.1	6.4	5.2	92.3	624.2	168.5	12.3	37.4	19.4	31.0	62.3	3.9	1.6
	Mar	22.3	6.2	13.5	7.9	4.1	0.87	1.1	0.9	6.2	4.8	8.2	490.4	113.3	3.2	27.5	21.7	12.5	30.3	9.4	39
	Apr	16.5	2.3	10.2	9.7	4.9	0.05	0.04	7.0	1.3	33.5	8.3	629.3	305.2	4.3	38.5	32.2	22.5	40.5	28.5	5.2
	May	2.2	12.3	18.5	5.3	10.2	0.31	0.02	0.72	0.98	15.6	9.6	932.5	396.5	2.9	41.0	52.5	41.5	42.3	35.8	0.28
	June	26.2	29.6	17.2	8.5	9.1	4.5	2.1	0.6	0.54	4.1		502.4	182.4	2.9	30.6	41.8	58.9	30.0	7.2	0.8
	July	29.3	41.0	18.9	19.3	11.9	4.2	1.1	0.35	0.64	2.0		705.3	150.3	3.5	20.5	28.3	77.2	21.6	3.9	0.23
	Aug	85.3	11.2	21.5	6.8	0.45	7.7	3.4	1.2	1.1	8.8		416.8	67.5	4.3	18.4	30.5	94.2	10.1	10.1	0.62
	Sep	32.5	21.3	37.5	7.8	3.5	10.1	4.5	1.5	0.34	10.5	2.9	209.6	50.3	18.5	39.2	18.7	80.9	10.1		2.4
1998	Oct	19.9	21.4	38.9	10.2		93	1.0	0.51	0.41	4.2	2.0	880.5	50.6	20.3	63.8	20.5	77.6	15.6		2.3
	Nov	13.4	5.3	35.3	4.0		8.2	0.88	1.6	0.61	1.9	1.0	820.5	31.6	40.5	54.5	38.5	80.5	41.6		3.9
	Dec	14.6	31.7	44.2	4.2		0.98	9.1	3.8	1.8	22.2	122.3	411.5	33.4	36.9	51.7	49.2	60.5	42.6	0.38	1.1
	Jan	13.5	29.0	58.9	22.3	0.98	0.62	53	2.4	2.1	14.8	138.4	505.3	58.9	14.5	44.8	20.5	33.7	50.2		6.2

Table 8. Temporal variation in biomass (gm/m²) of different dominant macrofaunal species in RS

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YEAR	MONTH	Dominant Macrofaunal Species																			
		Lh	Ml	Md	Pm	Bc	Da	Dr	Ps	Rs	Hs	Chr	Bb	Go	Dc	Tg	Tt	Brc	Gl	Pc	Gg
1996	Feb	0.001	1.46	2.69	0.05	0.014	0.13	0.003	0.001	0.06	0.02	0.01	67.9	8.35	0.28	30.2	3.11	17.7	1.83	0.04	0.17
	Mar	0.001	1.15	2.55	0.01		0.03	0.002	0.001	0.09	0.02	0.62	42.6	10.7	0.3	41.37	5.01	10.77	2.36	0.04	0.22
	Apr	0.001	0.52	1.85	0.04	0.008	0.11	0.024	0.002	0.01	0.02	0.003	65.7	6.3	0.15	21.8	3.11	8.23	0.74	0.03	0.15
	May	0.002	0.30	1.29	0.03	0.07	0.12	0.03	0.002	0.05	0.02	0.001	66.92	1.28	0.28	12.7	2.17	10.86	0.40	0.02	0.07
	June	0.003	0.67	1.52	0.03	0.13	0.08	0.05	0.002	0.04	0.03	0.001	68.7	1.23	0.31	11.2	2.23	8.23	0.32		0.03
	July	0.005	0.58	2.08	0.04	0.07	0.30	0.02	0.001	0.04	0.04		34.5	0.51	0.48	6.16	0.84	6.26	0.05		0.01
	Aug	0.005	1.41	2.36	0.03	0.01	2.61	0.03	0.001	0.005	0.04	0.001	21.4	1.08	0.88	12.8	0.68	8.92	0.09		0.04
	Sep	0.003	1.06	3.71	0.02		0.23	0.02	0.001	0.001	0.07	0.001	57.2	2.63	2.14	21.83	1.71	36.11	0.46		0.06
	Oct	0.001	1.33	3.02	0.02	0.002	1.09	0.04	0.002	0.04	0.03	0.001	45.1	4.41	1.07	21.2	2.67	56.07	1.43		0.06
	Nov	0.002	1.24	2.37	0.02	0.02	1.31	0.06	0.001	0.09	0.02	0.006	120.3	3.34	1.44	23.2	3.85	65.51	2.32		0.05
	Dec	0.001	0.69	3.45	0.03		0.98	0.05	0.001	0.08	0.01	0.007	115.6	4.36	0.74	30.1	2.47	71.47	2.26	0.03	0.09
	Jan	0.001	0.67	5.54	0.08	0.04	0.43	0.08	0.002	0.06	0.02	0.03	86.5	5.86	0.21	21.7	3.15	53.88	2.08	0.07	0.12
1997	Feb	0.003	1.55	3.98	0.06	0.022	0.17	0.02	0.001	0.12	0.02	0.005	49.2	6.89	0.33	28.1	2.29	196	227	0.06	0.24
	Mar	0.003	0.45	1.99	0.02		0.07	0.006	0.001	0.04	0.03	0.004	41.8	7.35	0.76	15.72	4.49	21.08	2.41	0.21	0.14
	Apr	0.003	0.73	1.92	0.02	0.012	0.07	0.03	0.003	0.05	0.03	0.01	47.9	4.1	0.09	13.4	3.31	10.94	0.95	0.14	0.11
	May	0.005	0.45	1.42	0.01	0.01	0.08	0.02	0.002	0.03	0.03	0.002	45.2	2.73	1.07	13.5	3.85	13.57	0.63	0.09	0.07
	June	0.006	0.66	2.11	0.01	0.08	0.10	0.01	0.002	0.08	0.03		36.1	2.38	0.91	10.9	2.42	9.78	0.44	0.03	0.02
	July	0.007	0.65	1.85	0.03	0.07	1.59	0.01	0.001	0.05	0.05		14.1	0.39	2.29	6.62	1.02	5.92	0.05		0.02
	Aug	0.005	0.71	2.01	0.02		4.06	0.01	0.001	0.05	0.06		17.7	0.99	1.3	10.4	0.77	9.96	0.08		0.03
	Sep	0.003	0.77	2.31	0.02		0.98	0.04	0.001	0.04	0.05	0.001	22.7	1.41	2.04	6.7	1.32	8.01	0.23		0.05
	Oct	0.003	1.74	2.91	0.03		0.37	0.01	0.001	0.01	0.04	0.001	22.7	6.83	1.36	20.2	3.41	47.7	1.34	-	0.06
	Nov	0.002	1.55	3.66	0.04	0.04	0.56	0.06	0.001	0.09	0.03	0.003	81.98	5.03	3.52	25.4	3.12	72.3	1.94		0.04
	Dec	0.001	1.20	3.52	0.03	0.003	0.57	0.09	0.002	0.09	0.02	0.004	68.2	3.69	1.42	29.8	3.49	74.8	1.97		0.04
	Jan	0.002	1.41	6.07	0.04	0.01	0.39	0.11	0.002	0.10	0.01	0.02	91.7	4.79	0.25	27.8	3.03	47.12	1.88	0.10	0.04

Table 9. Monthly variation in biomass (gm/m²) of different dominant macrofaunal species in SS

YEAR	MONTH	Dominant Macrofaunal Species																			
		Lh	Ml	Md	Pm	Bc	Da	Dr	Ps	Rs	Hs	Chr	Bb	Go	Dc	Tg	Tt	Brc	Gl	Pc	Gg
1996	Feb	0.001	1.69	3.81	0.003	0.002	0.01	0.001	0.001	0.08	0.04	0.06	172.9	1.32	0.83	6.12	0.77	18.7	0.23	0.02	0.06
	Mar	0.001	0.23	0.61	0.03	0.03	0.14	0.05	0.001	0.29	0.05	0.02	136.9	1.95	0.41	5.98	1.46	20.8	0.16		0.22
	Apr	0.001	1.05	1.01	0.05	0.05	0.13	0.02	0.003	0.12	0.35	0.007	182.8	1.55	0.26	7.04	1.60	18.12	0.17	0.26	0.20
	May	0.001	1.14	1.05	0.01	0.08	0.03	0.001	0.001	0.05	0.05	0.003	242.1	3.69	0.19	9.72	2.88	50.85	0.17	0.02	0.02
	June	0.001	1.96	0.92	0.06	0.13	0.4	0.02	0.001	0.04	0.05	0.002	177.9	2.39	0.21	6.13	3.91	68.23	0.15	0.07	0.06
	July	0.005	1.45	0.63	0.04	0.008	0.43	0.01	0.001	0.004	0.06		114.1	1.38	0.13	4.20	3.53	76.26	0.09	0.13	0.01
	Aug	0.006	1.69	1.39	0.02	0.005	0.51	0.01	0.001	0.01	0.02		45.2	0.84	0.14	4.68	3.71	68.91	0.03	0.10	0.04
	Sep	0.004	2.08	1.99	0.01		237	0.05	0.001	0.01	0.01	0.001	56.6	0.76	1.52	5.19	2.29	66.11	0.02		0.12
	Oct	0.002	2.65	2.09			1.07	0.02	0.001	0.008	0.002	0.005	93.19	0.74	2.17	6.02	1.42	55.01	0.04		0.05
	Nov	0.002	2.11	2.47	0.01		0.92	0.02	0.002	0.04	0.02	0.001	70.7	0.32	2.17	7.44	1.92	45.5	0.05		0.26
	Dec	0.002	2.16	2.8	0.05	0.01	0.17	0.12	0.001	0.06	0.12	0.09	11.2	0.51	3.10	8.64	2.28	61.5	0.14	0.47	0.07
	Jan	0.001	3.57	3.13	0.08	0.001	0.14	0.15	0.002	0.07	0.14	0.15	109.2	0.73	1.98	5.34	1.97	43.9	0.21	0.68	0.07
1997	Feb	0.002	2.11	1.94	0.001	0.001	0.03	0.01	0.001	0.26	0.06	0.05	138.4	2.00	0.92	5.55	1.46	29.7	0.28	0.06	0.08
	Mar	0.002	0.32	0.64	0.03	0.04	0.11	0.02	0.001	0.26	0.06	0.004	108.7	1.31	0.24	4.09	1.63	11.08	0.13	0.14	0.21
	Apr	0.002	0.12	0.48	0.04	0.05	0.01	0.001	0.002	0.05	0.38	0.004	139.5	3.63	0.32	5.71	2.42	19.9	0.19	0.39	0.28
	May	0.001	0.63	0.87	0.02	0.11	0.04	0.001	0.001	0.04	0.18	0.005	206.7	4.72	0.21	6.09	3.94	33.6	0.19	0.52	0.01
	June	0.003	1.51	0.81	0.03	0.09	0.6	0.03	0.001	0.02	0.05		11.4	2.17	0.22	4.53	3.14	49.78	0.14	0.10	0.04
	July	0.003	2.09	0.89	0.07	0.12	0.55	0.02	0.001	0.03	0.02		156.3	1.79	0.26	3.04	2.13	65.92	0.09	0.31	0.01
	Aug	0.009	0.57	1.01	0.02	0.005	1.01	0.05	0.001	0.04	0.10		92.4	0.81	0.33	2.73	2.31	79.97	0.04	0.15	0.03
	Sep	0.001	1.09	1.76	0.03	0.04	1.32	0.07	0.001	0.01	0.12	0.001	46.5	0.61	1.39	5.81	1.41	68.01	0.04		0.13
	Oct	0.002	1.09	1.83	0.04		1.21	0.01	0.001	0.02	0.05	0.001	195.2	0.62	1.52	9.46	1.54	67.8	0.07		0.12
	Nov	0.001	0.27	1.66	0.01		0.13	0.14	0.001	0.07	0.26	0.06	91.2	0.40	2.75	7.66	3.69	52.3	0.19	0.62	0.06
	Dec	0.001	1.61	2.08	0.01		0.13	0.14	0.001	0.07	0.26	0.06	91.2	0.40	2.75	7.66	3.69	52.3	0.19	0.62	0.06
	Jan	0.001	1.48	2.77	0.08	0.01	0.08	0.09	0.001	0.08	0.17	0.08	112.1	0.71	1.08	6.64	1.54	27.1	0.22		0.33

and Moitra (1975) and Barbhuyan and Khan (1992) reported the peak in oligochaete number in November. Sarkar (1989) found oligochaetes abundance in summer as well as in winter. Malhotra *et al.* (1990) observed the peak density during July. Monsoon peak was also observed by Gupta (1976) and Singh (1989) which holds true for RS and SS during the present investigation.

Hirudinea

Besides postmonsoon peak, the density and biomass of Hirudinea were negligible in both the lakes (Fig. 10B). Population density was highest during January ($5.44/\text{m}^2$ in RS and $110.29/\text{m}^2$ in SS) and in biomass also in January ($0.27 \text{ gm}/\text{m}^2$ in RS and $0.32 \text{ gm}/\text{m}^2$ in SS). Like Oligochaeta, Hirudinea showed higher representation in SS than RS may be due to the higher percentage of occurrence of *Vallisneria* sp. in SS, the most preferred macrophyte associated/inhabited by hirudinean as revealed from statistical analysis (please vide infra).

The three species comprising this group were *Hemiclepsis marginata asiatica*, *Hirudinaria manillensis* and *Placobdella emydae*. But they were very poorly represented both in number and percentage in RS and SS.

Singh and Roy (1991) observed maximum number of annelid population including Hirudinea in January that corroborates the present investigation in both the lakes. Postmonsoon peak may be explained by the monsoon breeding activities and the higher abundance of preferred plants *Vallisneria* sp. in these two Lakes.

Crustacea

The number and percentage of crustaceans were found to be slightly higher in SS ($68.39/\text{m}^2$) than RS ($60.73/\text{m}^2$). It showed marked seasonal fluctuation, increasing during postmonsoon ($120.8/\text{m}^2$ in RS and $138/\text{m}^2$ in SS) [Fig. 10C]. Biomass also followed more or less the same pattern, though during March biomass fall abruptly in SS, due to the presence of less amount of submerged vegetation and lower level of dissolved oxygen, which further confirmed from statistical interpretation (Please vide chapter 4.9).

Crustaceans were represented by two dominant species *Macrobrachium dayanum* and *Macrobrachium lamarrei*. Both the species were found throughout the study period. The population density of *Macrobrachium dayanum* increases considerably during January and February ($86.21/\text{m}^2$ in RS and $81.02/\text{m}^2$ in SS) and in case of *Macrobrachium lamarrei* peak density was also observed in the same month ($30.21/\text{m}^2$ in RS and $70.02/\text{m}^2$ in SS). Biomass followed the similar peaks as in case of density for both the species. Gupta (1976) noticed the peak presence of *Macrobrachium lamarrei* in August, September and December. Present investigation indicates the winter peak of this species.

Arachnida

The population did not exhibit any definite seasonal pattern (Fig. 10D). They were most infrequent in occurrence and represented by 13 species, but no dominant/regularly

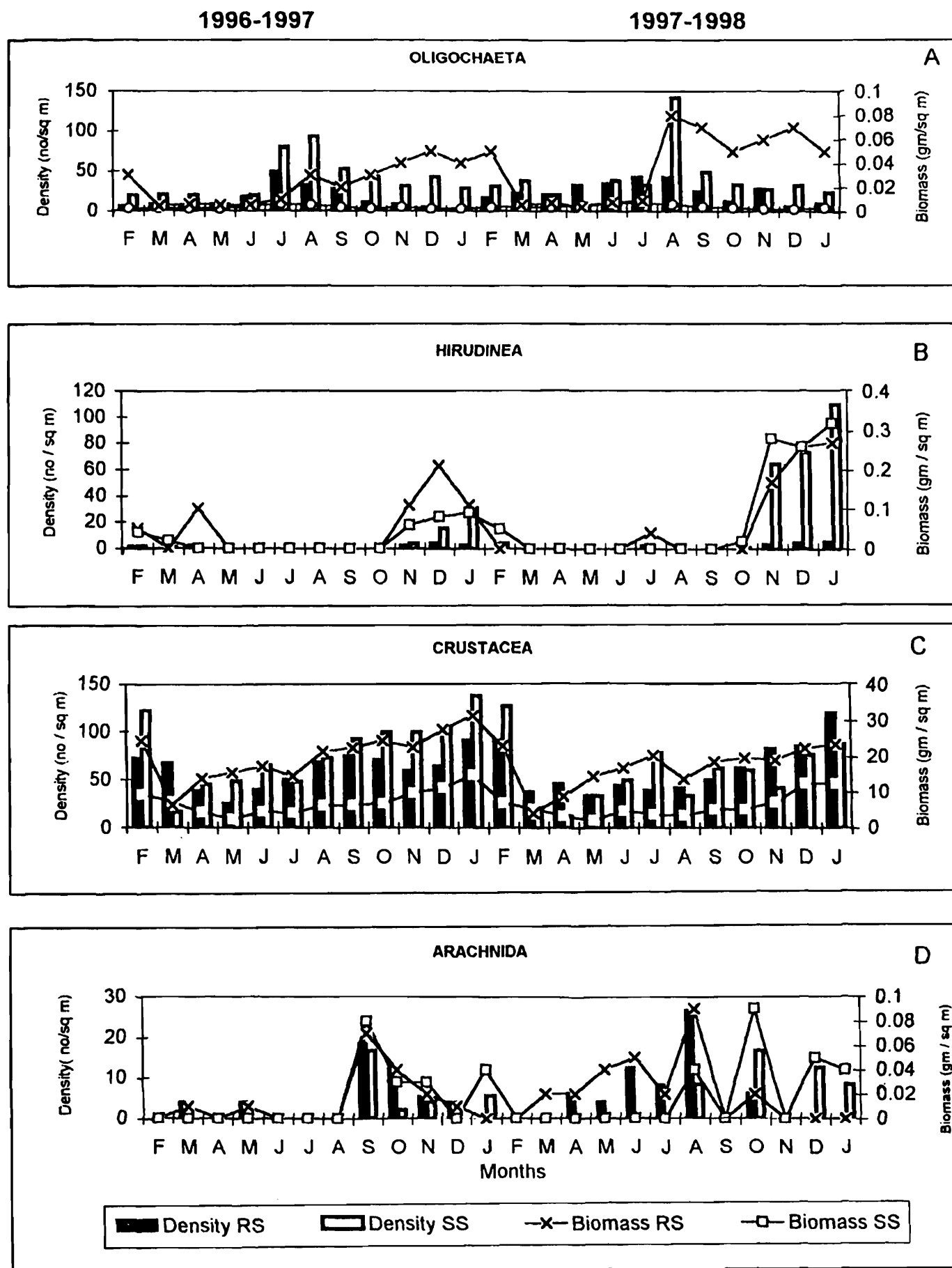


Fig. 10 (A-D) Population density and biomass distribution pattern of different macrofaunal groups in Rabindra Sarovar and Subhas Sarovar.

occurring species was found during the study period. Both mean density and percentage frequency of arachnid population were higher in RS (5.24/m², 0.37%) than SS (3.09 m², 0.24%) probably due to higher density of floating vegetation in RS.

Ephemeroptera

The presence of ephemeropteran larvae among the aquatic macrophytes of these two lakes was similar to the observation of Macan (1949) and Singh (1989). The ephemeropterans, not regular in occurrence in the present study, were represented by very low frequency during monsoon in both the lakes. Low abundance of ephemeropteran larvae during monsoon finds support from previous workers like Singh (1989) and Singh and Roy (1991).

After completion of a single year survey in RS, Srivastava (1986) reported two distinct peaks for Ephemeroptera, one in March and other in July. But during present investigation only a single peak was observed in February in RS and in March in SS. This might be due to the change of habitat and ecological condition of the lakes during last ten years. Mean density was higher in SS (3.02/m²) than RS (1.78/m²) indicating the higher pollution status of RS than SS.

Odonata

Odonate larvae are known to use the aquatic plants for egg laying site (Singh, 1989). Fischer (1961) pointed out that these larvae occur more in the water bodies having aquatic weeds. In the present study odonates regularly represented by good numbers in both the lakes which were well supported by aquatic macrophytes.

Peak density was observed in June–July in both RS and SS (29.15/m² in RS and 66.66/m² in SS) whereas lowest density was recorded during September in RS (4.16/m²) and no representative in October in SS (0/m²) [Fig 10F]. Biomass did not exactly follow the similar trends but peak and trough were not so varied particularly for the two dominant / regularly occurring species viz., *Pseudagrion microcephallum* and *Brachythemis contaminata*. *Pseudagrion microcephallum* showed peak density during January (20.56/m² in RS and 22.32/m² in SS) and lowest density in May in RS (3.16/m²) and in February in SS (0.02/m²). In the month of June peak density of *Brachythemis contaminata* (12.45/m² in RS and 12.32/m² in SS) was observed for both the lakes. Srivastava (1986) observed peak density during May and lowest density in November. Singh (1989) noted the peak density in August to September and lowest in April. Sinha *et al.* (1991) observed the peak in September and trough in January. Kumar and Roy (1994) noted two peaks, one in December and the other in June. In general, it appears that there is no such specific seasonal abundance in population distribution pattern of odonates. It may be possible that the species of odonates breed throughout the year. Srivastava (1986) reported the peak density of Zygoptera in the month of February. Kumar and Roy (1994) reported trimodal peaks of dragonfly nymphs in their abundance, i.e. in June, September and December. In the present investigation only a single peak of dragon fly larvae was observed in June, both

in terms of density as well as in biomass. It is interesting to note that there is an inverse type of relationship between the population density of *Brachythemis contaminata* and that of ephemeropteran larvae indicating apparently a perfect balance between the odonate predator and the ephemeropteran prey (Srivastava, 1986).

Hemiptera

The biannual average density of this group was higher in RS (22.21/m², 1.58%) than SS (12.88/m², 0.99%), which may be due to the higher macrophytic density and diversity (Table 5). In both the lakes monsoon peak was preceded by premonsoon trough, both in abundance and biomass. But in December 1997 a certain rise in density was observed in RS (Fig. 10G). Singh and Roy (1991) observed the peak density of Hemiptera during postmonsoon period, while Singh (1989) and Sinha and Roy (1991) reported the monsoon peak. Rai and Sharma (1991) categorised Hemiptera as free moving forms comparatively less associated group with macrophytes. It is interesting to note that all four regularly occurring species viz., *Diplonychus annulatus*, *Diplonychus rusticus*, *Plea* sp. and *Ranatra sordidula* showed their peak density in different months. In RS, *Diplonychus annulatus* showed the peak in August (31.21/m²), *Diplonychus rusticus* in January (7.2/m²), *Plea* sp. in April (8.32/m²) and *Ranatra sordidula* in March (2.82 /m²). In SS also, *Diplonychus annulatus* showed the peak in September (18.21/m²) *Diplonychus rusticus* in January (9.5/m²), *Plea* sp. in April (10.10/m²) and *Ranatra sordidula* in March (7.12/m²). This is an interesting example of temporal differentiation in the abundance of dominant species in the community.

Coleoptera

The population density and distribution percentage of Coleoptera were significantly higher in SS (15.96/m², 1.23%) than RS (3.25/m², 0.23%). During April the density as well as biomass reached the highest level in SS (79.96/m², 0.81gm/m²) [Fig 10K]. But in RS the distribution of Coleoptera was more or less uniformly moderate all over the year excepting slight increase in August. Peak density of Coleoptera in April was reported by Singh and Roy (1991) and argued that during summer death and decay of emergent plants took place resulting in high rate of detritus production providing favourable condition for growth and abundance of coleopterans. On the other hand, peak in August/September was reported by Singh (1989), Sinha and Roy (1991) and Sharma and Rai (1991).

The sole coleopterian species that was regular in occurrence was *Hydrocoptus subvittulus*. The population pattern was characterised by a remarkable surge in September in RS and in April in SS. This might be due to the higher abundance of floating and marginal macrophytes during that season. Low population density of coleopterans may be due to predator pressure as well as competition for space and availability of food.

Diptera

The mean density and percentage frequency of this group were observed to be higher in SS (40.85/m², 3.16%) than RS (10.36/m², 0.75%). They showed prominent seasonal

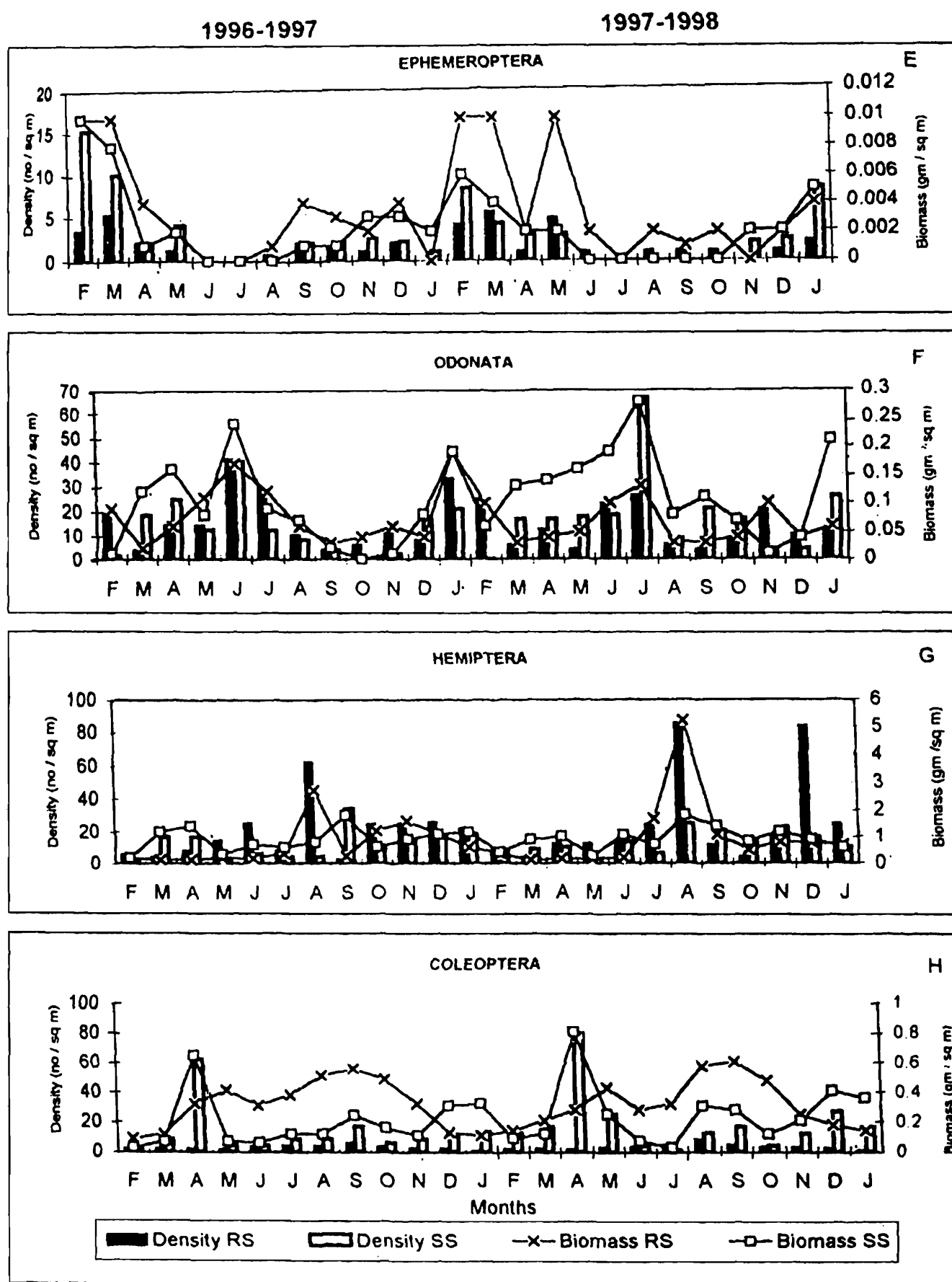


Fig. 10 (E-H) Population density and biomass distribution pattern of different macrofaunal groups in Rabindra Sarovar and Subhas Sarovar.

trend of greater abundance and higher biomass during winter ($66.64/\text{m}^2$, $1.52\text{gm}/\text{m}^2$ in RS and $251.07/\text{m}^2$, $1.4\text{gm}/\text{m}^2$ in SS; Fig 10 I).

Amongst the dipterans, *Chironomus* larvae were most dominant. They showed peak density during winter which finds support from a number of earlier workers (Mondal and Moitra, 1975; Bass, 1986; Gupta and Pant, 1986; Malhotra, 1990; Singh and Roy, 1991; Barbhuyan and Khan, 1992 and Bais *et al.*, 1992).

Gastropoda

This was the largest group of macrofauna associated with macrophytes in terms of density and distribution percentage frequency in both the lakes (Table 5 Fig. 10 J). The gastropod abundance varied from $2527.40/\text{m}^2$ (November) to $183.27/\text{m}^2$ (July) in RS and from $1924.25/\text{m}^2$ (October) to $432.77/\text{m}^2$ (September) in SS. It has been observed that the density of gastropod did not show exactly similar pattern during next year. The difference in population abundance is attributed to deweeding activity and density of macrophytes. Gastropods were represented by 14 species of which seven species were regular in occurrence viz., *Bellamya bengalensis*, *Gabbia orcula*, *Digoniostoma cerameopoma*, *Thiara granifera*, *Thiara tuberculata*, *Brotia costula*, *Gyraulus labiatus*. *Bellamya bengalensis* was one of the most significant species associated with macrophyte. Temporal variation over a period of two years showed that its population remained moderately high throughout the year, decreasing only during the monsoon (Tables 6 and 7). The density was maximum in October ($585.63/\text{m}^2$ in RS) and in May ($1092.3/\text{m}^2$ in SS), and minimum in the month of July ($63.56/\text{m}^2$ in RS) and September ($209.6/\text{m}^2$ in SS).

In Subhas Sarovar the peak density was shown during premonsoon period by gastropods like *Gabbia orcula*, *Thiara granifera*, *Thiara tuberculata* and *Gyraulus labiatus*, while it was in December for *Digoniostoma cerameopoma* and in July for *Brotia costula* (Table 7). In Rabindra Sarovar though these six species were present in fairly good number in all the season the peak was shown in March by *Gabbia orcula*, *Thiara granifera*, *Thiara tuberculata* and *Gyraulus labiatus*, in September by *Digoniostoma cerameopoma* and in December by *Brotia costula* (Table 6). The biomass of the above species also followed almost the same pattern. The differences observed in biomass relate to the presence of higher number of healthy/mature organism and in case of density due to increase in the number of immature/juvenile individual in the population.

Molluscan dominance was reported by several workers (Singh, 1989; Sarkar, 1989 and 1992; Malhotra *et al.*, 1990) which is in agreement with the present study and is attributed to soft organically rich bottom (Datta and Malhotra, 1986) and absence of pollution (Olive and Dambach, 1973). Gastropods constituted 89.44% and 82.87% of the total macrophyte associated macrofauna of RS and SS respectively (Table 5). Oommachan and Behare (1985) and Rao *et al.* (1987) observed high molluscan population in shallow niches and lowest in deeper zones. Presence of macrophyte flora and substratum characterisation explain most of the differences in the distribution of gastropod in the littoral zone of lakes

(Okland, 1990). Mouthon (1992) argued that the littoral dwelling gastropods have particular affinity for lakes with high organic matter. Although Singh and Roy (1991) reported the peak density of gastropods during premonsoon period but a number of workers like Singh (1984), Sarkar (1992) and Pandey *et al.* (1994) reported the postmonsoon peak that was in accordance to the present investigation. The monsoon trough corroborated with the workers mentioned above including Singh and Roy (1991). *Bellamya bengalensis*, *Gabbia orcula*, *Thiara granifera* and *Thiara tuberculata* were the most dominant species of the group Gastropoda in RS and SS. The monthly variation in their density determines the variation in the percentage and density of Gastropoda. Khan (1984) noted that viviparids breed continuously throughout the year because of moderate food supply in tropical waters. Muley (1977) suggested that *Thiara* spp. are continuous breeder and adults were found all round the year as observed in the present investigation. Sarkar (1992) reported the postmonsoon peak of *Viviparus* (= *Bellamya*) *bengalensis* and Gupta and Pant (1986) reported the peak in June. Postmonsoon peak was also supported from the present findings of RS and SS in Calcutta.

Bivalvia

In RS and SS, the bivalve group did not show any regular patterns of monthly variation (Fig. 10K), mainly due to the fact that different bivalve species had different temporal abundance. The bivalve density and biomass pattern were influenced by the presence of *Lamellidens* which increased the biomass value to a considerable level. Of the 4 species of bivalves recorded, *Parreysia caerulea* and *Lamellidens corrianus* were rarely observed in quantitative sampling. *Pisidium clarkeanum* and *Lamellidens marginalis* were common in occurrence in these two lakes. Mandal and Moitra (1975), Vasisht and Bhandal (1979) and Bonacina *et al.* (1991) reported the presence of these two species in ponds, lakes and reservoirs. In the littoral zone where oxygen is not a limiting factor, bivalves seem to be more sensitive than gastropods (Mouthon, 1992) especially with respect to sediment containing high levels of calcium salts (Aho, 1966). They utilise mainly detritus and algae and are able to exploit areas with maximum food supply (Kaushal and Tyagi, 1989). The abundance of bivalves in SS is more than RS, probably due to presence of more leaf litter/detritus in SS (Table 5).

Pisces

The weed fishes include 12 species in these two lakes of which only one species *Glossogobius giuris* was regular in occurrence, while others were infrequent in nature. In RS during 1996–'97 two peaks were observed, one in November 1996 and the other in February 1997 (Fig. 10L). In SS, although weed fishes were present throughout year in fairly good number, postmonsoon showed somewhat greater value. Weed fishes were chiefly present in the littoral areas of the lake, where dense aquatic weeds were recorded. (Prakash *et al.*, 1994). The density of *Glossogobius giuris* was found to be higher during winter season (Table 6 and 7) may be due to the higher macrophytic density.

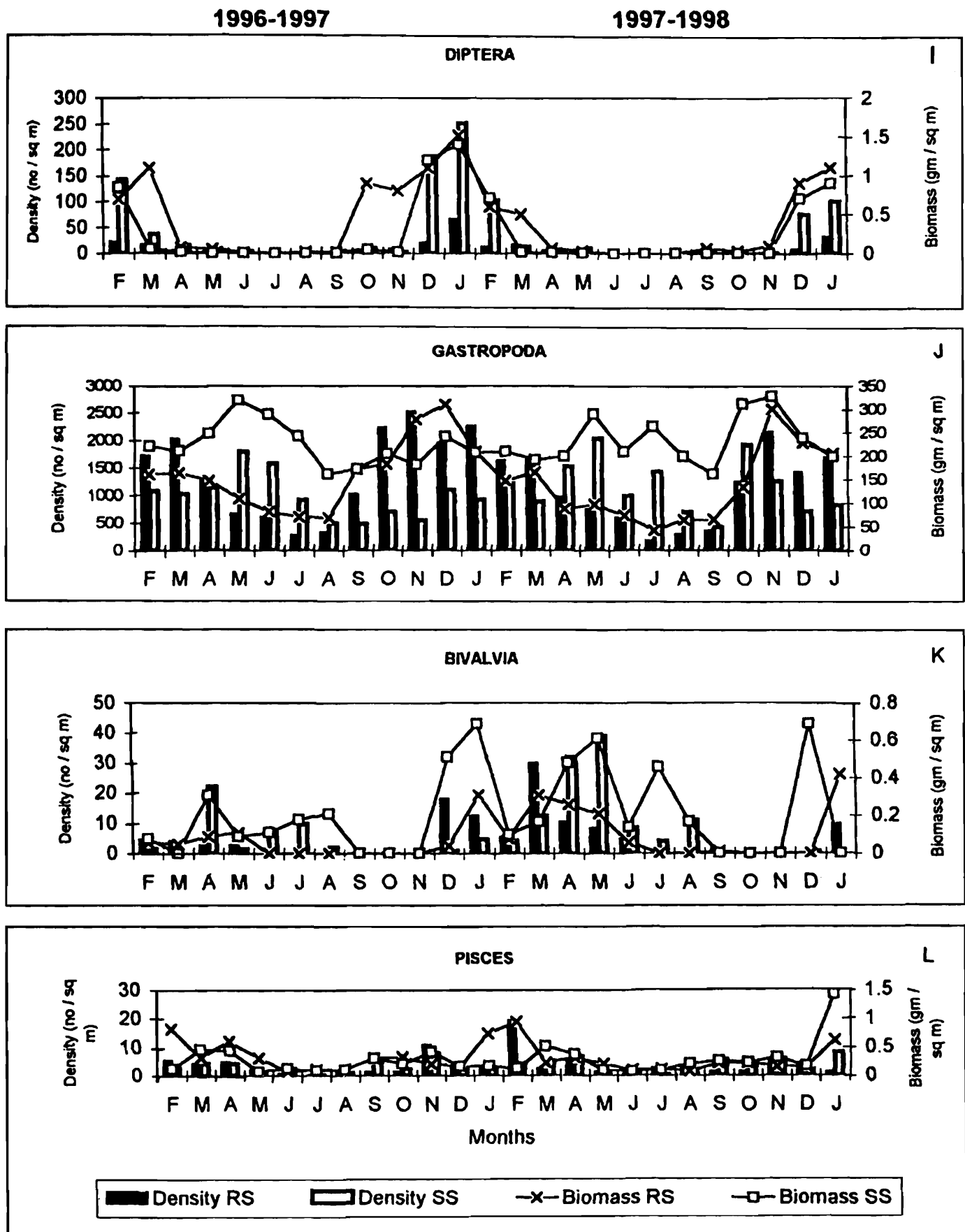


Fig. 10 (I-L) Population density and biomass distribution pattern of different macrofaunal groups in Rabindra Sarovar and Subhas Sarovar.

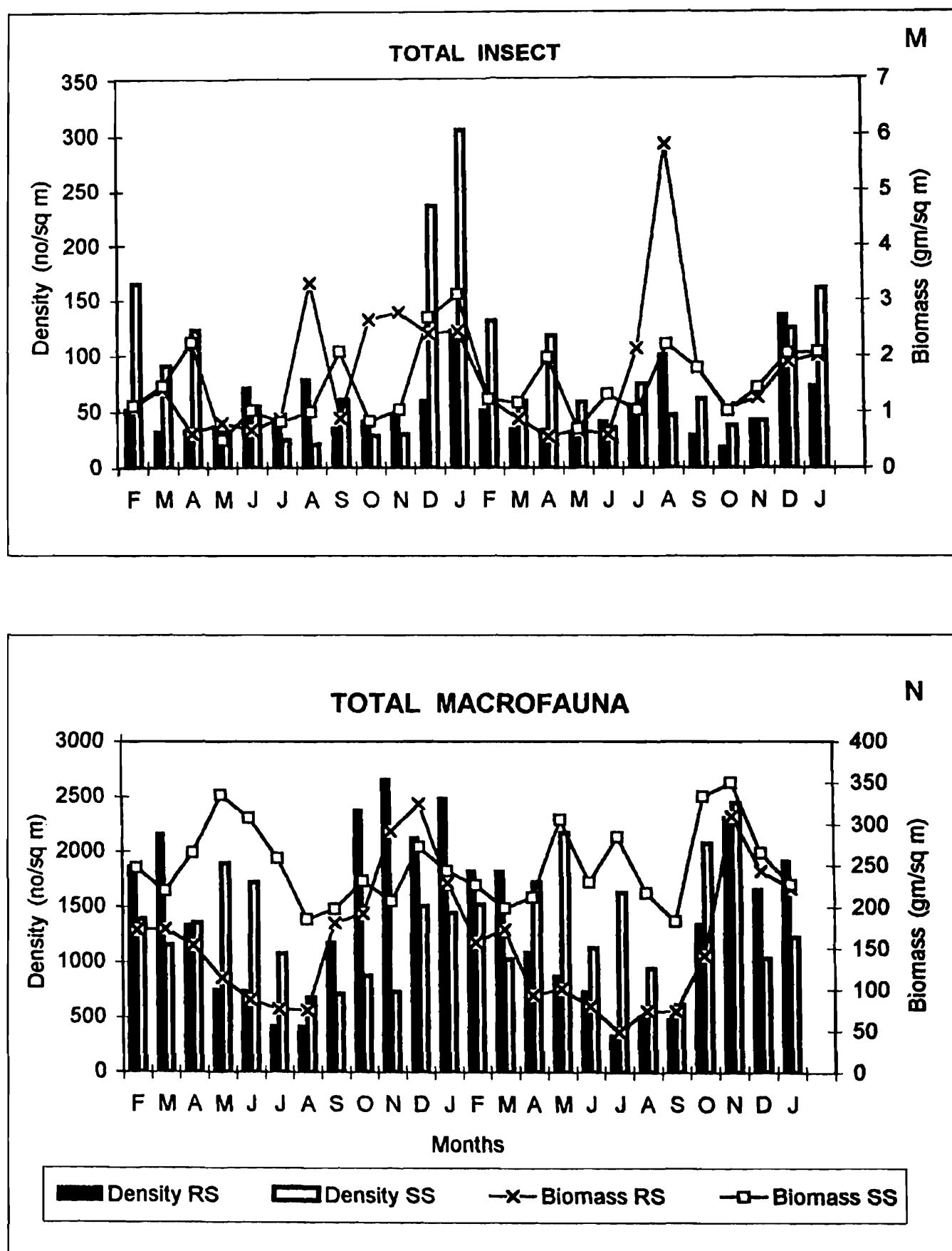


Fig. 10 (M-N) Population density and biomass distribution pattern of different macrofaunal groups in Rabindra Sarovar and Subhas Sarovar.

Total Insect

In both the lakes minimum density was observed during monsoon whereas minimum biomass was recorded in premonsoon, but maximum density as well as biomass was observed during postmonsoon (winter) period (Fig. 10M). This indicates that insects breed in winter that leads to immature stages during premonsoon and mature/adult stages during monsoon. Gupta (1976) reported the peak density of insect larvae during winter and minimum in monsoon. But Malhotra *et al.* (1990) found just the opposite result i.e. monsoon peak and winter trough. On the other hand, Singh and Roy (1991) reported premonsoon peak and monsoon trough. Actually the peak season varies on the basis of species composition, their breeding season and availability of their preferable food.

Total Macrofauna

The biannual variation of total macrofaunal density showed approximately similar seasonality during the two consecutive years (Fig. 10N). The density of total macrofauna ranged from 334.17/m² (July) to 2659.87/m² (November) in RS and 611.87/m² (September) to 2172.12/m² (May) in SS.

Remarks

The nature of substrate and available detritus control the composition and distribution of benthic fauna in an aquatic system (Cummins *et al.*, 1972). In these two lakes under study decaying organic matter are more or less abundantly available. The green vegetation along the embankments as well as decomposition of aquatic macrophytes are the primary source of leaf litter into the lakes. Moreover, the bottom of both the lakes are muddy (mainly clay and silt) with high organic enrichment that favours positive establishment of macrophytes as well as associated animal communities especially gastropod, crustaceans and insects.

Gupta (1976) stressed that aquatic vegetation plays an important role in an aquatic ecosystem for harbouring macrofauna. According to Schramm *et al.* (1987) epiphytic macroinvertebrate can be many time more abundant than invertebrates living in the bottom sediments (Richardson, 1921; Needham, 1929; Gerking, 1957). The submerged and emergent macrophytes provide excellent diverse niches for several insects both larvae and adult and also for molluscs. (McLachlan, 1975; Soszka, 1975; Gupta, 1976; Maitland, 1978).

The higher population density of macrofauna in Rs (1395.75/m²) than SS (1294.23 m²) was probably related to the macrophytic density and diversity which was much higher in RS than SS. Moreover, in SS, the macrophytes were extensively removed for angling purposes from time to time, thus destroying the natural habitat of associated macrofauna.

Thienemann (1925) considered that a lake bed producing more than 1000 individuals /m², should be considered as highly productive. Gupta (1982) argued that Nainital lake (Uttar Pradesh) was hyper eutrophic as the mean annual density of different macrobenthic

species was calculated as 1655/m². Bose and Lakra (1994) reported two mesotrophic ponds in Ranchi as their benthic density varied from 730–2943/m². In the present investigation, the mean annual density of RS (1395.75/m²) and SS (1294.23/m²) exceeds the above values. Hence, keeping in view with the suggestion of these authors it can be concluded that both the lakes are highly productive in nature.

Although there is no consensus about causes of seasonal variations in benthic population. The fluctuations in the distribution and abundance of different forms of aquatic organisms from year to year and within the same year attributed to distribution of their habitat by Holme (1961), corroborating the earlier observations of Anderson and Hooper (1956), Ruggles (1959), Oliver (1960) and later by Gupta (1976) in freshwater impoundment. Different authors have attributed seasonal variations to different causes, such as life cycle pattern (Whitlatch, 1977), food quality and quantity (Cowell and Vodopich, 1981), biotic interactions of competition and predation (Kajak and Dusoge, 1968), changes in particle size (Sanders, 1958) and macrophytic diversity. (Schramm *et al.*, 1987).

The population density of macrofauna in the present investigation was found higher during winter in RS but during summer in SS. The lower density was observed during monsoon in both the lakes probably due to the habitat destruction and rise in water level during monsoon. Severe fall in population due to heavy rainfall has also been reported by Singh and Roy (1991) and Khan and Chaudhuri (1984). Juvenile recovery of the population density, however, was quick, as the density had increased considerably in the following month. This is probably due to the fact that gastropods mainly *Bellamya bengalensis* and *Thiara granifera* breed round the year, as immature stages of these species were found throughout the study period (1996–'98).

The temporal variation in the total macrofaunal biomass was ranged from 48.43 gm/m² (July) to 324.44gm/m² (December) in RS, while 182.4 gm/m² (September) to 334.87gm/m² (May) in SS. (Fig. 10N). The benthic macroinvertebrate biomass has been reported to be similar to the distribution of total abundance by authors like Sarkar (1989) and Wones and Larson (1991). The temporal variations in the biomass of macrophyte associated macrofaunal organism in both RS and SS were, in general, in accordance with the population density pattern. Monthly fluctuation may be due to the presence of certain macrofaunal species having higher biomass value like *Bellamya bengalensis*, *Thiara granifera*, *Thiara tuberculata* and *Brotia costula* etc.

4.8. Community Analysis

The structure and functioning of the animal communities and the impact of nature or man induced change on them has meagre understanding. To understand a particular biotic community or assemblage it is very important to work out some indices of species structure. Environmental indices have been used to monitor the environmental standards or quality of the environment and these indices were widely used by several workers like Mac Arthur and Wilson (1967), Mac Arthur (1972), May (1975, 1976), Cody and Diamond (1975), Pianka (1976 a, b), Savage (1982) and Ghosh and Banerjee (1996).

Five indices, namely, Shannon–Weiner species diversity index, index of species richness, index of dominance, evenness index and Sorensen's index of similarity were employed and estimated in the present investigation. Besides these five indices, cluster analysis between the different stations of RS and SS is also taken into consideration as it provides a visual or graphic method for examining and interpreting levels of affinities between groups (Sneath and Sokal, 1973).

4.8.1. *Shannon – Weiner index of diversity*

The most widely used index for estimating the species diversity is the Shannon–Weiner index (Shannon and Weiner, 1949) given by the formula-

$$\bar{H} = -\sum (n_i / N) \log(n_i / N)$$

Where,

$\bar{H}$ = Shannon – Weiner index

n_i = Importance value of each species (number of individuals, biomass, production etc.)

N = total of importance value

This index is one of the best for making comparisons where one is not interested in separating out diversity components because it is reasonably independent of sample size. The value of this index can theoretically range from zero to infinity. However, values normally range from 0 to 4. Wilhm and Dorris (1968), after examining diversity in a range of polluted and unpolluted streams, concluded that the value of $\bar{H}$ greater than 3 indicated clean water, values in the range of 1 to 3 were characterised by moderately polluted conditions and values less than 1 characterised by heavily polluted condition.

4.8.2. *Species richness*

One of the major components of species diversity is 'Species richness' or variety components or Margalef's diversity index (d) and is expressed by simple ratio between total species (s) and total number or importance values (N).

$$d = \frac{s-1}{\log N} \text{ as proposed by Margalef (1958)}$$

This index commonly varies between 1 and 5, and larger the index a more healthy body of water. When it tends towards 1 pollution is thought to increase and a damage should be suspected.

4.8.3. *Index of dominance*

Within a major community there are species or groups which largely control the energy flow and strongly affect the environment of all other species. They are known as ecological

dominants (Odum, 1971). The degree to which dominance is concentrated in one or many species can be expressed by an appropriate index of dominance that sums each species importance in relation to the community as a whole. The index of dominance (Simpson, 1949) is the sum total of squares of the proportion of the species in the community and is expressed as –

$$c = \sum (n_i / N)^2$$

Where, c = index of dominance
 n_i = importance value for each species
 N = total of importance value.

The value of 'c' varies between 0 and 1. Higher diversity values reflect diversified resources in the habitat available for components of the community. Decreased values indicate increase by an average species resulting in the lowering of the number of coexisting species in the community.

4.8.4. Evenness Index

Another major component of diversity is 'evenness' or 'equitability' in the apportionment of individuals among the species. It is expressed as

$$e = \frac{\bar{H}}{\log S} \quad (\text{Pielou, 1966})$$

Where,
 $\bar{H}$ = Shannon – Weiner index
 S = number of species

It can be noted that both 'e' and $\bar{H}$ behave inversely to the index of dominance since high values indicate a low concentration of dominance.

4.8.5. Sorensen's index of similarity

Similarity indices had popular use in the field of ecology, particularly as a basis for quantifying similarities between the communities of different sampling site. The index of similarity or quotient of similarity (Q_s) between two samples as proposed by Sorensen (1948) are calculated as follows :

$$Q_s = \frac{2c}{a+b}$$

where,
 a = number of species in sample one
 b = number of species in sample two
 c = number of species common to both

It measures the similarity in the species composition in the sample and the value of Q_s ranges between 0 to 1. Value zero indicates complete dissimilarity where as value 1 denotes maximum similarity between samples (or communities).

Here the scores have been multiplied by 100 to give a percentage scale. Mountford's (1962) technique was followed to classify the percentage similarity values and for construction of dendrogram.

Maximum, minimum and mean values of different indices for different stations of RS and SS are presented in Table 10. Diversity indices are used to measure the stress in the environment. In estimating the species diversity probably the most widely used index is the Shannon–Weiner index. Several authors have questioned the use of Shannon's diversity index stating that it depends upon a hypothetical number of species and must be considered as an empirical value (Peet, 1974). Washington (1984) cited a lack of exploration of its biological relevance. But most of the criticisms have been subjective. Actually $\bar{H}$ values have an applied importance as they give additional information, which ultimately help the ecologists to formulate the hypothesis about the environment. Harrel *et al.* (1976) stated that the diversity values should always be used to compliment tabular analysis of taxa distribution and abundance with physico-chemical data.

According to Whittaker (1977) the Shannon–Weiner index is actually not a real assessment of the species diversity in a community but it represents the relative importance value of the species taken into account. That is why the index obtained by the formulae is a good indication of water quality of the habitat and forms a base for biomonitoring. Hughes (1978) discussed factors other than pollution that could affect $\bar{H}$ values and concluded that they were useful indices of community structure but cannot stand alone. Wilhm and Dorris (1968) and Staub *et al.* (1970) suggested the utility of the species diversity index in assessing water quality. In the present study, mean observed value of Shannon – Weiner diversity index was found to be highest at station 3 of RS (2.47) and station 2 of SS both with polyspecific vegetation. Mean value of $\bar{H}$ in case of RS is 2.43 whereas 2.19 in case of SS. After application of the relationship put forwarded by Wilhm and Dorris (1966) between the diversity values and pollution status it can be concluded that both the lakes are at intermediate state of environmental stress and pollution.

Species diversity was termed as 'non-concept' by Hurlbert (1971) and was meaningless because to him the diversity index which is necessarily linear in nature, does not represent the actual situation. But, Hill (1973) suggested that it is an extremely useful notation that can be defined as the effective number of species present, either in a broader geographic area, a community or a portion. The number of species present in a community is variously referred to as 'species richness' and/or species diversity. Various indices of diversity weight these two components rather differently (Hill, 1973) and some indices all but ignore one component or the other (Pianka and Huey, 1971). Mason (1981) quoted from a number of studies that the species richness is better and more realistic indicator of diversity than information statistics. The 'species richness' (d) values ranged from 2.33–4.91 with mean value 3.9 in RS while in SS it varied from 1.56 – 4.98 with mean value at

3.88. The higher diversity values reflect the suitability of habitat for the organism in one hand while on the other the high species diversity has been reported to be correlated with longer food chain and complex food web of the ecosystem and also relatively more stable community (Margalef, 1956). Larger the index value, a more healthy body of water. On the basis of mean value it is evident from the Table 10 that the station 2 of SS can be considered a comparatively healthy one while station 1 of RS is the poorest one.

A widely used approach to describe the responses of biotic communities to environmental change has been the calculation of dominance diversity indices (Modde and Drewes, 1990). However, Winget and Mangum (1979) and Hawkes (1979) argued that dominance diversity indices are ineffective in evaluating several forms of environmental influences. But Pinaka (1976a and 1976b) stressed on index of dominance (c), which is sample size dependent and reflects the proportional abundance of species richness and individual richness. Mac Arthur (1965, 1972) explained the diversity variation on the basis of resource, resource utilisation and niche overlap. The index of dominance is always higher where the community is dominated by a fewer number of species and lower where the dominance is shared by a large number of species (Whittaker, 1965), or the total population of the community is uniformly distributed among different species that mainly occur in clean and pollution free waters (Osborne *et al.*, 1976). In the present study, the values ranged from 0.07–0.66 in RS and 0.10–0.70 in SS. The mean values were slightly higher in SS (0.38) than RS (0.29). Thus following Mac Arthur's (1965 and 1972) explanation, it can be inferred that the habitats of these two lakes have diversified resources with lower diversity of their utilisation by an average species, providing a condition for higher co-existence of species as well as high amount of niche overlap i.e. sharing of resources among the coexisting species. Lower value of this index indicate that there is fairly uniform distribution of different species of macrofauna reflecting moderately clean and relatively pollution free water of both RS and SS.

The 'evenness component of diversity' or evenness based on Shannon – Weiner diversity index is thought to denote a balanced relation between the species and individual richness of a sample. The values were found to range between 0.89 and 3.08 with mean value at 2.01 in RS and between 1.03 and 3.0 with mean value at 1.83 in SS. The values show a greater equitability in the apportionment of individuals among the species in both RS and SS.

A coefficient of similarity (Sorensen's index of similarity) was computed to compare the macrofaunal population associated with macrophytes occurring at each station of RS and SS (Table 10). It is evident that faunal similarity was greatest between RS 3 and SS 2 (90%) followed by similarity between RS 2 and SS 1 (86%). These four stations represent comparatively higher species diversities. The minimum faunal similarity was found between RS 2 and SS 2 (31%).

Similarity indices have also been used as a basis for cluster analysis, showing affinities between samples and thus providing a baseline for monitoring programmes. Classification (Dendrogram) analysis for the present investigation (Fig. 11) showed 3 prominent clusters

(A, B and C) and 2 intermediate clusters (D and E). Cluster 'A' denotes the cluster for the sites with partially shady, undisturbed with polyspecific vegetation. Cluster 'B' is made between the sites with sunny exposure and ample submerged vegetation but slightly disturbed. Cluster 'C' is comprised of the sites that are shady and undisturbed and with the combination of floating and submerged macrophyte. Cluster 'D' is an intermediate cluster comprising of species collected mostly from cluster 'A' and 'C', whereas cluster 'E' is also an intermediate cluster between 'D' and 'B'

On the basis of foregoing findings and discussion it can be concluded that the habitats of RS and SS are moderately polluted presumably with no obvious stress as these two lake macrophytal communities are stable apparently with long food chain and complex food web. Furthermore, from the cluster 'A' it can be inferred that the station 3 of RS and station 2 of SS showed highest similarity between these two sites, possibly these two being highly diverse macrophyte associated habitats supporting higher species diversity. It can also be inferred that the resources in the habitats of both the lakes are diversified and components of the communities share the resources to a high extent, which have favoured the existence of diversified species.

Faunal similarity index values between pairs of sampling sites

	RS-2	RS-3	SS-1	SS-2	SS-3
RS-1	0.697	0.659	0.356	0.621	0.722
RS-2		0.685	0.861	0.314	0.678
RS-3			0.414	0.905	0.672
SS-1				0.666	0.572
SS-2					0.624

RS-1= Station1 of Rabindra sarovar SS-1=Station1 of subhas sarovar

RS-2= Station2 of Rabindra sarovar SS-2=Station2 of subhas sarovar

RS-3= Station3 of Rabindra sarovar SS-3=Station3 of subhas sarovar

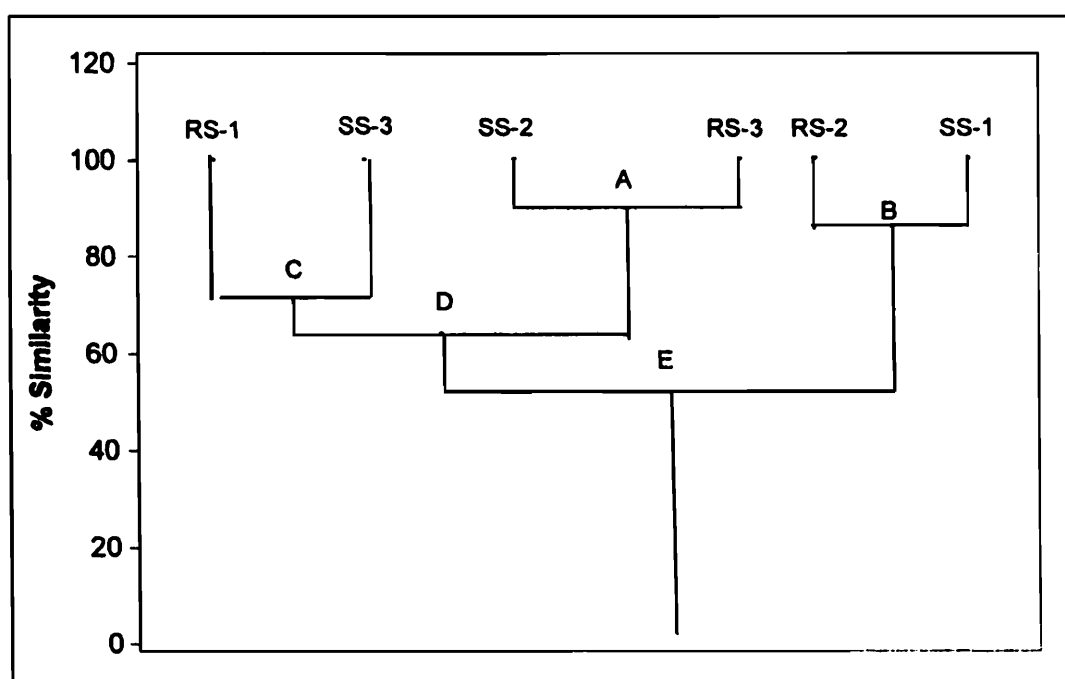


Fig. 11. Dendrogram showing percentage similarity values of the six selected sampling sites.

Table 10. Community indices values of Rabindra Sarovar and Subash Sarovar

INDICES	Range of Values (Mean)							
	Rabindra Sarovar				Subash Sarovar			
	Station-1	Station-2	Station-3	Average	Station-1	Station-2	Station-3	Average
$\bar{H}$	1.43–3.63 (2.37)	1.12–3.47 (2.44)	1.74–3.47 (2.47)	1.12–3.63 (2.43)	1.07–3.07 (2.05)	1.10–3.43 (2.29)	1.20–3.61 (2.22)	1.07–3.61 (2.19)
d	2.51–4.91 (3.39)	2.33–4.62 (4.15)	3.58–4.9 (4.16)	2.33–4.91 (3.9)	1.87–4.58 (3.37)	1.56–4.98 (4.43)	2.11–4.87 (3.84)	1.56–4.98 (3.88)
c	0.16–0.43 (0.30)	0.07–0.66 (0.29)	0.10–0.55 (0.27)	0.07–0.66 (0.29)	0.23–0.67 (0.40)	0.12–0.60 (0.37)	0.10–0.70 (0.38)	0.10–0.70 (0.38)
e	1.52–3.08 (1.97)	0.89–2.95 (2.02)	1.22–2.79 (2.03)	0.89–3.08 (2.01)	1.03–2.61 (1.76)	1.10–2.63 (1.88)	1.30–3.0 (1.86)	1.03–3.0 (1.83)

$\bar{H}$ = Shannon–Weiner index of diversity, **d** = Species richness, **c** = Index of dominance, **e** = Evenness index

4.9. Statistical Analysis

There is no universal dispersion pattern of parameters or uniform distribution of individuals or species. The parameters or properties of individuals vary from species to species and from time to time in the same species. So for the purpose of drawing reliable and valid inferences, samples need statistical treatment. In an aquatic ecosystem the distribution and abundance of each species at a particular place though dependent upon a combination of biological and/or physicochemical factors, the relationship may or may not exist between every pair of parameters/or species. Various environmental variables were subjected to different statistical analysis (the methods of which are described in chapter-3, section 3.4.6.) as follows :

1. ANOVA– 2way analysis
2. Pearson's correlation coefficient
3. Stepwise multiple regression analysis.

4.9.1. ANOVA-2way analysis :

Based on 11 basic macrofaunal groups and 2 broad groups *viz.*, total insect and total macrofauna as test variables, ANOVA (Analysis of variance) was performed to find out the significant difference of macrofaunal abundance, if any, existing in relation to macrophytes, seasons, stations and lakes. The results are presented in Table 11.

The result showed significant differences in macrofaunal density indicated as no/100 gm wet weight of macrophytes i.e. in 12 out of a total of 13 groups except Hirudinea associated with six selected species of macrophytes. This type of significant differences between the macrophytes and macrofauna was also observed by Parsons and Matthews (1995). Seasonal or temporal variation of macrophyte associated macrofauna also showed significant difference with respect to 10 groups except Crustacea, Gastropoda and Pisces. Similar temporal variation was observed by Schramm *et al.* (1987) during their study on epiphytic macroinvertebrate in Orange and Henderson lakes, Florida. Temporal variability observed during the present study may be due to seasonal changes of the macrophytes and the different functional roles of macrophytes for epiphytic fauna. Two-way interactions also revealed significant values for most of the groups (9 out of 13) leaving aside Hirudinea, Ephemeroptera, Odonata and Pisces. Considering the different stations or sampling sites of RS and SS as experimental variables a marked difference with respect to sampling station was evident with the two groups *viz.*, Gastropoda and total macrofauna of RS and only with Hemiptera in SS. This may be due to relative uniformity in hydrobiological features of the stations, while a significant differences can be attributed to distribution, density and suitability of the submerged macrophytes sheltering gastropod and hemipteran species in these two lakes dominated by *Ceratophyllum* in RS but *Vallisneria* in SS. It may be mentioned that Bais *et al.* (1992) observed significant difference of total macrofaunal density amongst the 3 sampling stations or transects in case of Sagar Lake, Madhya Pradesh.

Table 11. Analysis of variance (2-way) of various macrofaunal groups in relation to macrophytes, seasons, stations and lakes.

Macrofaunal group	F Ratio and its significance											
	Macrophyte associated macrofauna			Rabindra Sarovar (RS)			Subhas Sarovar (SS)			RS X SS		
	Macro phytes (M) Df = 5	Seasons (S) Df = 2	MXS Df = 10	Stations (St) Df = 2	Seasons Df = 2	St x S Df = 4	Stations Df = 2	Seasons Df = 2	Stations x Seasons Df = 4	Lakes Df = 1	Seasons Df = 2	Lakes x Seasons Df = 2
Oligochaeta	9.785**	11.618**	2.507*	—	—	—	—	4.277*	—	13.04**	13.779**	—
Hirudinea	—	12.731**	—	—	8.171**	—	—	12.882**	—	5.766*	7.364**	5.710**
Crustacea	48.945**	—	5.168**	—	—	—	—	—	—	—	6.423**	—
Ephemeroptera	3.545**	9.902**	—	—	—	—	—	6.575**	—	—	15.084**	—
Odonata	6.528**	14.206**	—	—	—	—	—	5.237**	—	—	—	—
Hemiptera	15.858**	4.408*	4.192**	—	—	—	3.768*	—	—	3.865*	3.478*	—
Coleoptera	31.761**	20.534**	3.823**	—	—	—	—	4.118*	—	12.656**	—	—
Diptera	22.633**	18.772**	4.295**	—	6.886**	—	—	4.308*	—	5.408*	4.351*	—
Total Insect	5.107**	25.520**	2.322*	—	—	—	—	5.652**	—	5.137*	—	—
Gastropoda	45.192**	—	3.328**	4.899*	15.127**	—	—	—	—	—	16.471**	—
Bivalvia	9.787**	8.018**	4.479**	—	7.547**	—	—	7.811**	—	—	5.695**	—
Pisces	2.905*	—	—	—	—	—	—	—	—	—	3.873*	—
Total Macrofauna	33.697**	15.444**	3.396**	4.564*	16.812**	—	—	3.968*	3.875**	—	18.86**	9.783**

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

When the macrophyte associated macrofaunal density was compared between the two lakes, some significant differences were evident among five basic macrofaunal groups viz., Oligochaeta, Hirudinea, Hemiptera, Coleoptera and Diptera and one broad group viz., total insect. Seasonal differences were significant with all the groups except Odonata, Coleoptera and total insect, showing almost symmetrical distributional relationships of ten groups in both the lakes. Besides Hirudinea and total macrofauna, two-way interactions did not show any significant result, considering combined spatio-temporal differences of lakes and seasons.

4.9.2. Pearson's correlation coefficient

From ANOVA it is evident that stational/spatial variations were not so pronounced in both the lakes. So for the uniformity and accessibility both physicochemical and biological data were pooled for further statistical analysis based on fortnightly values of 17 physicochemical parameters and 25 baseline biological parameters (6 macrophytes and 19 macrofauna). The mean values of these parameters are used as independent (physicochemical parameters) or dependent (biological parameters) variables for this purpose.

Pearson's correlation coefficients were calculated to determine a relationship between biotic and abiotic factors as well as among the biotic factors (between macrophyte and macrofauna). Only the significant results at 5% and 1% level of significance were considered and denoted by single asterisk (*) and double asterisk (**) respectively in the tables (12 to 19). Besides, negative r values prefixed by negative (-) sign and positive value without any prefix in the respective tables.

A. Correlation coefficient between physicochemical parameters and macrofaunal abundance (no/m²)

The correlation between physicochemical parameters and macrofaunal abundance is furnished in Tables 12 and 13.

Total macrofauna is found to bear positive correlation with dissolved oxygen and nitrate, no correlation with COD, hardness and turbidity and negative correlation with other twelve physicochemical parameters in RS. In SS only phosphate shows negative correlation, while other 16 parameters exhibit no correlation. Highest positive correlation is shown with NO_3 ($r = 0.6200^{**}$) in RS.

Total insect population displays positive correlation with dissolved oxygen and nitrate whereas negative correlation with air and water temperature, free carbon-di-oxide and total dissolved solid in both the lakes. Besides these parameters conductivity, phosphate, nitrite and ammonium also have shown negative correlation with total insect abundance in SS. In both the lakes total insect population is highly influenced by DO ($r = 0.6162^{**}$ in RS and 0.7274^{**} in SS). Among the different macrofaunal groups Oligochaeta is positively correlated with air and water temperature, free carbon-di-oxide, total alkalinity, total

Table 12. Correlation Coefficient (r value) between physicochemical parameters and macrofaunal abundance (no/m²) in RS and SS.

8

LAKE	PHYSICO CHEMICAL PARAMETERS	r value with total macrofauna and different groups												
		T.Macf	Oli	Hir	Crus	Eph	Odo	Hem	Col	Dip	T.Ins	Gas	Biv	Pis
R A B I N D R A	At	-.5976**	.4242*	-.7199**	-.8321**	—	—	—	—	-.6619**	-.5373**	-.5627**	—	—
	Wt	-.6646**	.5325**	-.6967**	-.8019**	—	—	—	.5260**	-.7561**	-.4892*	-.6337**	—	—
	DO	.4692*	-.84594*	.6011**	.7589**	—	—	.4367*	—	.6469**	.6162**	.4446*	—	—
	BOD	-.5271**	—	—	-.6718**	—	—	—	—	—	—	-.5040*	—	—
	COD	—	—	—	—	—	—	—	-.4252*	—	—	—	.4629*	—
	FCO ₂	-.7693**	.6814**	-.6096**	-.7719**	—	—	—	.5053*	-.6800**	-.4436*	-.7459**	—	—
	pH	-.4304*	—	-.5197**	-.5812**	—	—	—	—	—	—	—	—	—
	TA	-.5496**	.5120*	-.5965**	—	—	—	—	—	—	—	-.5423**	—	—
	Con	-.6150**	—	-.5021*	-.5238**	—	—	—	—	-.4123*	—	-.5953**	—	—
	Hard	—	—	—	—	.6759**	—	—	—	—	—	—	.4150*	—
	TDS	-.7562**	.5160**	-.5014*	-.7122**	—	—	—	—	-.5638**	-.4403*	-.7382**	—	-.5063*
	Tur	—	—	—	—	-.7174*	—	—	—	—	—	—	-.5266*	—
	Cl	-.6702**	.4327*	-.5475**	-.7463**	—	—	—	—	-.4342*	—	—	-.6508**	—
	PO ₄	-.7531**	.6961**	—	-.5109*	-.4457*	—	—	—	-.4212*	—	-.7493**	—	-.4507*
	NO ₂	-.5539**	.5345**	—	—	-.4851*	—	—	.7743**	-.4144*	—	-.5708**	-.5114*	—
S U B H A S	NO ₃	.6200**	-.5004*	.7582**	.7595**	—	—	—	—	.5855**	.5270**	.5974**	—	—
	Amon	-.5144	.5972**	—	—	-.5465**	—	—	.5901**	-.4259*	—	-.5278**	—	—
	At	—	—	-.7966**	-.5157*	—	—	—	—	-.6876**	-.6194**	—	—	—
	Wt	—	—	-.6770	-.5069*	-.5532**	—	—	—	-.8184**	-.8019**	—	—	—
	DO	—	—	.5926**	.5875**	—	—	—	—	.8136**	.7274**	—	—	—
	BOD	—	—	-.4529*	—	.4293*	—	-.4793*	—	—	—	—	.4628*	—
	COD	—	—	—	—	—	—	—	.4494*	—	—	—	—	—
	FCO ₂	—	.4857*	-.5657**	-.4748*	—	—	—	—	-.5826**	-.5434**	—	—	—
	pH	—	—	-.6395**	—	—	—	—	—	—	—	—	—	—

Table 12. *Contd.*

LAKE	PHYSICO CHEMICAL PARAMETERS	r value with total macrofauna and different groups												
		T.Macf	Oli	Hir	Crus	Eph	Odo	Hem	Col	Dip	T.Ins	Gas	Biv	Pis
S A R O V A R	TA	—	—	-.4756*	—	—	—	—	—	—	—	—	.4242*	—
	Con	—	—	—	-.5162**	—	—	—	.4273*	-.5705**	-.4255*	—	.4943*	.4371*
	Hard	—	-.4175*	—	-.5157**	—	—	—	.5715**	—	—	.4420*	.5499**	—
	TDS	—	—	—	—	-.5051*	—	—	—	-.4491*	-.4828*	—	—	-.4741*
	Tur	—	—	—	—	-.6843**	—	—	—	—	—	—	—	—
	Cl	—	—	—	—	—	—	-.4331*	—	—	—	.4411*	—	—
	PO ₄	-.4396*	.7739**	—	—	-.5401*	—	—	—	—	-.4460*	—	—	—
	NO ₂	—	.5335**	—	—	-.4722*	—	—	—	-.4353*	-.4415*	—	—	—
	NO ₃	—	—	.7609**	.4675*	—	—	—	—	.5696**	.5192**	—	—	—
	Amon	—	—	—	-.4201*	-.4930*	.4947*	—	—	-.5937**	-.5577**	—	—	—

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

For full name of abbreviation vide list of abbreviation

dissolved solid, chloride, phosphate, nitrite and ammonium in RS and with free carbon-di-oxide, phosphate and nitrite in SS. Negative correlation is revealed with dissolved oxygen and nitrate in RS and with hardness in SS but PO_4 is the common factor in both the lakes which shows highest control ($r = 0.6961^{**}$ in RS, 0.7739^{**} in SS) over the oligochaete abundance.

The density of Hirudinea exhibits a strong positive relationship ($p < 0.01$) with dissolved oxygen and nitrate in both the lakes whereas negative relationship with At, Wt, FCO_2 , pH, TA, Con, TDS and Cl in RS and with At, Wt, BOD, FCO_2 , pH and TA in SS. From the result it is clear that NO_3 is the most important controlling factor ($r = 0.7582^{**}$ and 0.7609^{**} in RS and SS respectively).

The crustacean density shows positive relationship with DO and NO_3 in both the lakes whereas negative relation is found with At, Wt, FCO_2 , Con, Hard, and Amon in SS.

Arachnids are aerial arthropods and most infrequent group associated with emergent weeds. They show no such significant relationship in this study.

Ephemeropterans exhibit positive correlation with hardness and negative relation with turbidity, phosphate, nitrite and ammonium in RS. On the other hand Ephemeroptera shows positive relation with BOD and negative relation with six parameters (Wt, TDS, Tur, PO_4 , NO_2 and Amon) in SS.

Odonates show no correlation with any of the parameters studied except ammonium in SS ($r = 0.4947^*$).

Hemiptera shows positive relation with DO in RS and negative with BOD and Cl in SS.

Coleopterans have positive correlation with Wt, FCO_2 , NO_2 and Amon and negative with COD in RS whereas only positive r-value is observed with COD, Con and Hard in SS.

Diptera again shows the positive relationship with DO and NO_3 whereas negative relationship with At, Wt, FCO_2 , Con, TDS, NO_2 and Amon in both the lakes along with Cl and PO_4 in RS. Undoubtedly DO establish itself as the controlling factor ($r = 0.6469^{**}$ in RS and $r = 0.8136^{**}$ in SS).

Gastropoda, the most dominant group, exhibits similar type of result with parameters as shown by total macrofauna in RS. On the other hand only three parameters *viz.*, BOD, Hard and Cl express positive relationship with gastropod abundance in SS.

Bivalvia exhibits positive r-value with COD and Hard and negative with Tur and NO_2 in RS. In SS, BOD, TA, Con and Hard shows positive r-value.

Pisces or weed fishes show negative relationship with TDS and PO_4 in RS, while in SS positive relation is found only with conductivity and negative with TDS.

B. Correlation coefficient between physicochemical parameters and macrofaunal biomass (gm/m²)

Result shown in Table 13 reveals that total macrofaunal biomass in RS represents negative correlation with ten parameters, positive with two parameters and highest positive correlation with NO₃ ($r = 0.7631^{**}$). But in SS only single factor (TDS, $r = 0.4708^{*}$) shows positive relationship.

For oligochaete biomass most of the physicochemical parameters (8 parameters) show positive r -value in RS but in SS contrastingly most of the parameters (7 parameters) show negative r -value. Among the parameters FCO₂ shows maximum positive r -value ($r = 0.6450^{**}$).

NO₃ is the common factor which shows highest positive correlation with hirudinean biomass ($r = 0.8079^{**}$ and 0.7832^{**} in RS and SS respectively). In SS, besides NO₃, DO also have positive influence.

Crustacean biomass has expressed correlation with 12 parameters (2 positive and 10 negative) in RS and with 10 parameters (2 positive and 8 negative) in SS. Here also the NO₃ shows maximum positive r -value, 0.8936^{**} (RS) and 0.6260^{**} (SS). Like abundance arachnid biomass also fails to establish any significant relationship.

Ephemeropteran biomass shows positive correlation with hardness and dissolved oxygen in RS and SS respectively, while negative correlation is shown by 4 and 6 parameters in RS and SS respectively.

Biomass of Odonata shows no significant correlation in both the lakes except turbidity which expresses positive relation with odonate biomass ($r = 0.4947^{*}$) in SS.

Hemipterans exhibit positive r -value with NO₂ in RS and negative r -value with Hard in RS and with BOD in SS. However, all the r -values show significant correlation at 5% level of significance.

Coleoptera has shown positive correlation with At, Wt, FCO₂, TDS, NO₂ and Amon in RS but not shown any correlation with any parameter in SS.

Dipterans have positive correlation with DO and NO₃ in both the lakes, whereas shown negative with 11 and 6 parameters in RS and SS respectively.

Total insect biomass projects positive correlation with DO in RS ($r = 0.4639^{*}$) and NO₃ in SS ($r = 0.4820^{*}$).

The most dominant group, Gastropoda shows positive r value with DO ($r = 0.5091^{*}$) and NO₃ ($r = 0.7445^{**}$) in RS and TDS in SS ($r = 0.4895^{*}$).

Bivalvia shows preference towards hard water ($r = 0.4747^{*}$) and higher COD value ($r = 0.5039^{*}$) in RS but no such significant relationship observed in SS.

Pisces/weed fishes show only negative relationship with a number of physicochemical parameters in both the lakes (7 in case of RS and 4 in case of SS). It is observed that pisces avoid the higher water temperature ($r = -0.5793^{**}$ and -0.4941^{*} in RS and SS respectively).

Table 13. Correlation Coefficient (r value) between physicochemical parameters and macrofaunal biomass (gm/m²) in RS and SS.

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LAKE	PHYSICO CHEMICAL PARAMETERS	r value with total macrofauna and different groups												
		T.Macf	Oli	Hir	Crus	Eph	Odo	Hem	Col	Dip	T.Ins	Gas	Biv	Pis
RABINDRA SARA ROVARI	At	-.6544**	—	-.7393**	-.8922**	—	—	—	.5493**	-.7354**	—	-.6308**	—	-.4628*
	Wt	-.6753**	.4456*	-.7189**	-.9013**	—	—	—	.7162**	-.8068**	—	-.6531**	-.4132*	-.5793**
	DO	.5335**	—	—	.8459**	—	—	—	—	.6988**	.4639*	.5091*	—	—
	BOD	-.5328**	—	—	-.7064**	—	—	—	—	-.6059**	—	-.5158**	—	—
	COD	—	—	—	—	—	—	—	—	—	—	—	.5039*	—
	FCO ₂	-.7888**	.6450**	-.6930**	-.8820**	—	—	—	.5478**	-.8189**	—	-.7722**	—	-.4643*
	pH	-.4741*	—	-.5409**	-.5470**	—	—	—	—	-.4485*	—	-.4573*	—	—
	TA	-.6544**	.5256**	-.6370**	-.4900	—	—	—	—	—	—	-.6544**	—	—
	Con	-.7039**	—	-.5267**	-.7029**	—	—	—	—	-.5588**	—	-.6908**	—	—
	Hard	—	—	—	—	.6614**	—	-.4063*	—	—	-.4728*	—	.4747*	—
	TDS	-.7576**	.5174**	-.5479**	-.8393**	—	—	—	.4592*	-.7143**	—	-.7420**	—	-.4717*
	Tur	—	—	—	—	-.6664*	.5058*	—	—	—	—	—	-.4264*	—
	Cl	-.7419**	.5604**	-.6132**	-.7560**	—	—	—	—	-.5860**	—	-.7308**	—	—
	PO ₄	-.6328**	.7743**	—	-.5161**	-.4673*	—	—	—	-.6087**	—	-.6271**	—	-.5270**
	NO ₂	—	.4377**	—	—	-.4994*	—	.4196*	.6469**	-.4850*	—	—	-.4234*	-.4151*
SUBHAS	NO ₃	.7631**	-.4716*	.8079**	.8936**	—	—	—	—	.7094**	—	.7445**	—	—
	Amon	-.4088*	.5030*	—	—	-.5752**	—	—	.5514**	-.5154**	—	-.4112*	—	-.5128*
	At	—	-.4907*	-.7583**	-.5480**	—	—	—	—	-.7841**	-.5419**	—	—	-.6332**
	Wt	—	—	-.6739	-.4639*	-.6168**	—	—	—	-.8744**	-.5429**	—	—	-.4941*
	DO	—	—	.6121**	.5591**	.4634*	—	—	—	.8537**	—	—	—	—
	BOD	—	-.6324**	-.4685*	-.5574**	—	—	-.4415*	—	—	-.5183**	—	—	—
	COD	—	—	—	—	—	—	—	—	—	—	—	—	—
	FCO ₂	—	—	-.5985**	-.5136*	—	—	—	—	-.6208**	—	—	—	—
	pH	—	-.5388**	-.6343**	-.4907*	—	—	—	—	—	—	—	—	—

Table 13. Contd.

LAKE	PHYSICO CHEMICAL PARAMETERS	r value with total macrofauna and different groups												
		T.Macf	Oli	Hir	Crus	Eph	Odo	Hem	Col	Dip	T.Ins	Gas	Biv	Pis
S A R O V A R	TA	—	-.4916*	-.5397**	-.4344*	—	—	—	—	—	—	—	—	—
	Con	—	-.4136*	—	-.5894**	—	—	—	—	-.5690**	—	—	—	—
	Hard	—	-.5134*	—	-.5623**	—	—	—	—	—	—	—	—	—
	TDS	.4708*	—	—	—	-.5452*	—	—	—	-.4686*	—	.4895*	—	-.5899**
	Tur	—	—	—	—	-.6650**	—	—	—	—	—	—	—	—
	Cl	—	-.6025**	-.5062*	—	—	—	—	—	—	-.4408*	—	—	-.4256*
	PO ₄	—	—	—	—	-.5340*	—	—	—	—	—	—	—	—
	NO ₂	—	—	—	—	-.5538*	—	—	—	—	—	—	—	—
	NO ₃	—	.5196**	.7832**	.6260**	—	—	—	—	.6397**	.4820*	—	—	—
	Amon	—	—	-.4637*	—	-.5976**	—	—	—	-.5929**	-.4353*	—	—	—

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

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C. Correlation coefficient between physicochemical parameters and macrofaunal species in terms of abundance (no/m²) and biomass (gm/m²)

The calculated r-values between physicochemical parameters and dominant/regularly occurring species are taken into consideration for statistical analysis [Table 14 (A-B) and 15 (A-B)].

Amongst these species, *Limnodrilus hoffmeisteri* has positive correlation with eight parameters, maximum with phosphate ($r = 0.8100^{**}$), whereas negative with DO and NO₃ in RS. In SS, positive with three parameters, maximum with phosphate ($r = 0.8338^{**}$) but negative with only DO.

Crustacea is represented by two dominant species *Macrobrachium dayanum* (Md) and *Macrobrachium lamarrei* (Ml). Abundance and biomass of Md show positive relationship with DO and NO₃ for both the lakes ($p < 0.01$). Whereas in case of Ml both abundance and biomass show similar trend of positive correlation with DO and NO₃ in RS but only with DO in SS.

Odonata also represents 2 regularly occurring species viz., *Pseudagrion microcephallum* (Pm) and *Brachythemis contaminata* (Bc). Abundance of Pm shows positive r-value only with DO but negative with At, Wt, FCO₂ and TDS in RS and only with At in SS. In case of biomass no such positive relationship is projected for both the lakes. Both abundance and biomass of Bc express positive relationship with five parameters, maximum with PO₄ ($r = 0.6172^{**}$ and 0.6090^{**} for abundance and biomass respectively) in RS, whereas with seven parameters in SS; maximum with Cl ($r = 0.6688^{**}$ and 0.6527^{**} for abundance and biomass respectively).

Hemipterans are regularly represented by *Diplonychus annulatus* (Da), *Diplonychus rusticus* (Dr), *Plea* sp. (Ps) and *Ranatra sordidula* (Rs). Amongst them the Da shows positive relationship with NO₂ in RS and with PO₄ in SS, both in terms of abundance and biomass. Dr expresses its positive correlation with DO and NO₃ while Ps with COD both in terms of abundance and biomass in both the lakes. The species Rs shows only the negative significant r value with five parameters for biomass in RS, maximum with Wt ($r = -0.6460^{**}$ for abundance and -0.6407^{**} for biomass). But in SS it shows negative r-value with TDS, Tur, PO₄ and NO₂ both for abundance and biomass.

Hydrocoptus subvittulus, a dominant coleopteran species, expresses positive relationship with six parameters in terms of abundance and with five parameters in terms of biomass, highest with NO₂ ($r = 0.7454^{**}$ and 0.7329^{**} for abundance and biomass respectively) in RS. In SS only positive relationship are established with COD and Hardness.

Abundance of *Chironomus* sp. expresses positive relationship with DO and NO₃ in both the lakes while biomass also follows the same trend except in Rs where *Chironomus* has failed to represent any relationship.

The most dominant group Gastropoda is commonly represented by seven regularly occurring species, namely, *Bellamya bengalensis* (Bb), *Gabbia orcula* (Go), *Digoniostoma*

Table 14A. Correlation Coefficient (r value) between physicochemical parameters and macrofaunal species in terms of abundance(no/m²) in RS and SS.

LAKE	Macrofaunal Species		r value with Physicochemical parameters and macrofaunal species								
			At	Wt	Do	BOD	COD	FCO ₂	pH	TA	Con
RABINDRA SARKAR VARI	Oligochaeta	Lh	.4725*	.5885**	-.4639*	—	—	.7515**	—	.5856**	—
	Crustacea	Md	-.8783**	-.8477**	.7690**	-.6410**	—	-.7665**	-.6433**	—	-.5583**
		MI	-.4851*	-.4405*	.4167*	-.5830**	—	-.4806*	—	—	—
	Odonata	Pm	-.6092**	-.5793**	.4369*	—	—	-.4767*	—	—	—
		Bc	—	—	—	—	—	.4484*	.4723*	—	—
	Hemiptera	Da	—	—	—	—	—	—	—	—	—
		Dr	-.6866**	-.6233**	.6782**	—	—	-.6362**	-.5978**	-.5431**	-.4734*
		Ps	—	—	—	—	.4923*	—	—	-.4262*	—
		Rs	-.5874**	-.6460**	—	-.5845**	—	-.5520**	—	—	—
	Coleoptera	Hs	.4722*	.6125**	-.4373*	—	-.4672*	.6247**	—	—	—
	Diptera	Cs	-.7133**	-.7911**	.6776**	-.4192*	—	-.7088**	-.4209*	—	-.4441*
	Gastropoda	Bb	-.5500**	-.5950**	.4766*	—	—	-.6453*	—	-.5113*	-.5556**
		Go	—	-.44348	—	—	—	-.5036*	—	—	—
		Dc	—	—	—	—	—	—	—	—	—
		Tg	—	-.4547*	-.5729**	.4234*	—	—	-.6983**	—	—
		Tt	—	—	—	—	.7103**	-.4591*	—	-.7128**	—
		Brc	-.6676**	-.5992**	.5590**	-.5834**	—	-.7238**	-.6247**	-.7258**	-.7684**
		Gl	-.6520**	-.7448**	.4685*	-.5538**	—	-.7896**	—	-.5115*	-.5856**
	Bivalvia	Pc	—	—	—	—	.5458**	—	—	—	—
	Pisces	Gg	—	—	—	—	—	—	—	—	—
	Oligochaeta	Lh	—	—	-.5062*	—	—	.5720**	—	—	—
	Crustacea	Md	-.6415**	-.6747**	.6655**	—	—	-.5371**	-.4217*	—	-.4673*
		MI	—	—	.4586*	—	—	—	—	—	-.5017*
	Odonata	Pm	-.4220*	—	—	—	—	—	—	—	—
		Bc	.4664*	.4144*	—	.4745*	—	—	—	—	.4075*
	Hemiptera	Da	—	.4328*	-.4390*	—	—	—	—	—	—

Table 14A. *Contd.*

LAKE	Macrofaunal Species	r value with Physicochemical parameters and macrofaunal species								
		At	Wt	Do	BOD	COD	FCO ₂	pH	TA	Con
SUBHASHA SARROVA R	Dr	-.6371**	-.6203**	.6184**	-.5041*	—	-.5812**	—	-.4151*	-.5981**
	Ps	—	—	—	—	.6538**	—	—	—	—
	Rs	—	—	—	—	—	—	—	—	—
	Coleoptera Hs	—	—	—	—	.4532*	—	—	—	—
	Diptera Cs	-.7787**	-.8473**	.8595**	—	—	-.6255**	—	—	-.5701**
	Gastropoda Bb	—	—	—	—	—	—	—	—	—
	Go	.4775*	—	—	.7345**	—	.4296*	—	.4332*	.4291*
	Dc	-.4981*	-.4575*	.5387**	-.5858**	—	-.7198**	-.5082*	-.6586**	-.6267**
	Tg	—	—	—	—	—	-.4582*	—	—	—
	Tt	—	—	—	—	—	—	—	—	—
	Brc	—	.4583*	—	-.4991*	—	—	—	—	—
	Gl	—	-.6044**	.5727**	—	—	—	—	—	—
Bivalvia Pc	—	—	—	.4340*	—	—	—	.4100*	.4925*	
Pisces Gg	-.4086*	—	—	—	—	—	—	—	—	

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

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Table 14B. Correlation Coefficient (r value) between physicochemical parameters and macrofaunal species in terms of abundance(no/m²) in RS and SS.

LAKE	Macrofaunal Species		r value with Physicochemical parameters and macrofaunal species							
			Hard	TDS	Tur	Cl	PO ₄	NO ₂	NO ₃	Amon
R A B I N D R A S A R O V A R	Oligochaeta	Lh	—	.5962**	—	.5798**	.8100**	—	-.5953**	.5376**
	Crustacea	Md	—	-.6014	—	-.5527**	-.4116*	—	.4272*	—
		MI	—	-.6014**	—	-.5527**	-.4116*	—	.4272*	—
	Odonata	Pm	—	-.6282**	—	—	—	—	—	—
		Bc	—	—	.6850**	.4786**	.6172**	—	—	—
	Hemiptera	Da	-.4245*	—	—	—	—	.4138*	—	—
		Dr	—	-.4590*	—	-.5446**	—	—	.7792**	—
		Ps	—	—	—	—	—	-.4323*	—	—
		Rs	—	-.4979*	—	—	—	—	—	—
	Coleoptera	Hs	—	.4285*	—	—	—	.7454**	-.4099*	.5628**
	Diptera	Cs	—	-.6106**	—	-.4758*	-.4321*	—	.6457**	—
	Gastropoda	Bb	—	-.6582**	—	-.4790*	-.4132*	-.4435*	.6863**	-.5264**
		Go	—	—	-.5281**	—	-.6876**	-.5574**	—	-.5362**
		Dc	—	—	—	—	—	.6064**	—	.5383**
		Tg	—	-.4990*	-.4455*	-.4156*	-.7206**	-.4861*	.4439*	-.6142**
		Tt	—	—	—	-.4072*	-.5246**	-.5443**	—	—
		Brc	-.4579*	-.7351**	—	-.8269**	-.5138*	—	.8104**	—
		Gl	—	-.6940**	-.4375*	-.6599**	-.7595**	-.5716**	.5324**	.4839*
	Bivalvia	Pc	.6814**	—	-.4887*	—	—	-.5187**	—	—
	Pisces	Gg	.4978*	—	-.5210**	—	-.5883**	-.6110**	—	-.6098**
S U B H A S	Oligochaeta	Lh	—	—	—	—	.8338**	.5799**	—	—
	Crustacea	Md	-.4581*	-.4843*	-.4393*	-.4402*	—	—	.5187**	-.6190**
		MI	-.4396*	—	—	—	—	—	—	—
	Odonata	Pm	—	—	—	—	—	—	—	—
		Bc	.4660*	.4986*	—	.6688**	—	—	-.4603*	.5609**
	Hemiptera	Da	—	—	—	—	.5116*	—	—	—
		Dr	—	—	—	-.4344**	—	—	.6955**	-.4081*

Table 14B. *Contd.*

LAKE	Macrofaunal Species		r value with Physicochemical parameters and macrofaunal species						
			Hard	TDS	Tur	Cl	PO ₄	NO ₂	NO ₃
S A R O V A R	Ps	—	—	—	—	—	—	—	—
	Rs	—	-.5578**	-.4232*	—	-.5095*	-.4379*	—	—
	Coleoptera Hs	.4586*	—	—	—	—	—	—	—
	Diptera Cs	—	-.4253*	—	—	—	-.4161*	.6645**	-.5889**
	Gastropoda Bb	.4316*	—	—	.5001*	-.4525*	—	—	—
	Go	.7211**	—	—	.5985**	—	—	-.5528**	—
	Dc	—	—	—	-.6476**	—	—	.7993**	-.5911**
	Tg	—	—	—	—	-.4746*	—	-.4392*	—
	Tt	—	.5568*	.5640**	—	—	—	—	—
	Brc	-.4381*	.6218**	.4184*	—	.7179**	.6950**	—	.4951*
	Gl	—	—	—	—	-.7496**	-.4544*	—	—
	Bivalvia Pc	.5309**	—	—	—	—	—	—	—
	Pisces Gg	—	.6247**	—	-.4254*	—	-.4403*	—	-.4906*

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

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Table 15A. Correlation Coefficient (r value) between physicochemical parameters and macrofaunal species in terms of biomass (gm/m²) and SS.

LAKE	Macrofaunal Species		r value with Physicochemical parameters and macrofaunal species								
			At	Wt	Do	BOD	COD	FCO ₂	pH	TA	Con
RABINDRA SARA ROVRA	Oligochaeta	Lh	—	.5006*	-.4947*	—	—	.6823**	—	.5002*	—
	Crustacea	Md	-.8743**	-.8417**	.7657**	-.6401**	—	-.7623**	-.6437**	—	-.5588**
		MI	-.4781*	-.4301*	.4186*	-.5785**	—	-.4677*	—	—	—
	Odonata	Pm	-.5706**	-.6649**	—	—	—	—	—	—	—
		Bc	—	—	-.4061*	—	—	.4515*	.4867*	—	—
	Hemiptera	Da	—	—	—	—	—	—	—	—	—
		Dr	-.6709**	-.6011**	.7123**	—	—	-.6316**	-.4442*	-.5206**	-.4538*
		Ps	—	—	—	—	.5979**	—	—	—	—
		Rs	-.5987**	-.6407**	—	-.5737**	—	-.5432**	-.4095*	—	-.4170*
	Coleoptera	Hs	.4133*	.5453**	—	—	—	.5787**	—	—	—
	Diptera	Cs	—	—	—	—	—	—	—	—	—
	Gastropoda	Bb	-.5585**	-.6089**	.4834*	—	—	-.6565**	—	-.5169**	-.5423**
		Go	—	-.4461*	—	—	—	-.5050*	—	—	—
		Dc	—	—	—	—	—	—	—	—	—
		Tg	-.5162**	-.6289**	.4677*	-.4049*	—	-.7495**	—	-.4402*	—
		Tt	—	—	—	—	.5825**	-.4393*	—	-.5574**	—
		Brc	-.6689**	-.5972**	.5586**	-.5779**	—	-.7183**	-.6243**	-.7269**	-.7717**
		Gl	-.6451**	-.7397**	.4653*	-.5400*	—	-.7903**	—	-.5218**	-.5854**
	Bivalvia	Pc	—	—	—	—	.5331**	—	—	—	
	Pisces	Gg	—	—	—	—	—	—	—	—	
SUBHAS	Oligochaeta	Lh	—	—	-.4846*	—	—	.6429**	—	—	—
	Crustacea	Md	-.6973**	-.6934**	.6926**	-.4296*	—	-.6706**	-.4703*	-.4710*	-.5464**
		MI	—	—	.4596*	—	—	—	—	—	-.5016*
	Odonata	Pm	—	—	—	—	—	—	—	—	—
		BC	.4662*	.4203*	—	.4696*	—	—	—	—	—
	Hemiptera	Da	—	.4342*	-.4406*	—	—	—	—	—	—

Table 15A. *Contd.*

LAKE	Macrofaunal Species	r value with Physicochemical parameters and macrofaunal species								
		At	Wt	Do	BOD	COD	FCO ₂	pH	TA	Con
S A R O V A R	Dr	-.6626**	-.6423**	.6408**	-.4937*	—	-.5956**	—	-.4114*	-.5953**
	Ps	—	—	—	-.4431*	.4852*	—	—	—	—
	Rs	—	—	—	—	—	—	—	—	—
	Coleoptera Hs	—	—	—	—	.4197*	—	—	—	—
	Diptera Cs	-.7589**	-.8635**	.8550**	—	—	-.6309**	—	—	-.5950**
	Gastropoda Bb	—	—	—	—	—	—	—	—	—
	Go	.4804*	—	—	.7274**	—	-.4276*	—	.4269*	.4277*
	Dc									
	Tg									
	Tt									
	Brc									
	Gl									
	Bivalvia Pc									
	Pisces Gg	-.4020*	—	—	—	—	—	—	—	—

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

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Table 15B. Correlation Coefficient (r value) between physicochemical parameters and macrofaunal species in terms of biomass (gm/m²) in RS and SS.

LAKE	Macrofaunal Species		r value with Physicochemical parameters and macrofaunal species							
			Hard	TDS	Tur	Cl	PO ₄	NO ₂	NO ₃	Amon
R A B I N D R A S A R O V A R S U B H A S	Oligochaeta	Lh	—	.5500**	—	.5494**	.7478**	.4242*	.5229**	.5041*
	Crustacea	Md	—	-.6727**	—	-.7293**	-.4700*	—	.8006**	—
		MI	—	-.5917**	—	-.5420**	—	—	.4221*	—
	Odonata	Pm	—	-.5859**	—	—	—	—	—	—
		Bc	—	—	.6980**	.4813*	.6090**	—	—	—
	Hemiptera	Da	-.4250	—	—	—	—	—	—	—
		Dr	—	-.5391**	—	-.6451**	—	—	.8366**	—
		Ps	—	—	—	—	—	—	—	—
		Rs	—	-.4957*	—	—	—	—	—	—
	Coleoptera	Hs	—	.4134*	—	—	—	.7329**	—	.6048**
	Diptera	Cs	—	—	—	—	—	—	—	—
	Gastropoda	Bb	—	-.6541**	—	-.4827*	-.4147*	-.4487*	.6903**	-.5339**
		Go	—	—	-.5290**	—	-.6931**	-.5644**	—	-.5346**
		Dc	-.4372*	—	—	—	—	.6755**	—	.5696**
		Tg	—	-.5639**	-.4423*	-.4802*	-.7499**	-.4928*	.4960*	-.6242**
		Tt	.4423*	—	-.4614*	—	-.5688**	-.6256**	—	-.4878*
		Brc	-.4621*	-.7361**	—	-.8287**	-.5044**	—	.8098**	—
		Gl	—	-.6901**	-.4489*	-.6546**	-.7583**	-.5789**	-.5272**	-.4901*
	Bivalvia	Pc	.6450**	—	-.4864*	—	—	-.5109**	—	—
	Pisces	Gg	.4900*	—	-.5147*	—	-.5799**	-.6052**	—	-.6096**
S U B H A S	Oligochaeta	Lh	—	—	—	—	.7833**	.5377**	—	—
	Crustacea	Md	-.4960*	—	—	-.5149*	—	—	.6671**	-.6168**
		MI	-.4384*	—	—	—	—	—	—	—
	Odonata	Pm	—	—	—	—	—	—	—	—
		Bc	.4590*	.5089*	—	.6527**	—	—	-.4541*	.5620**

Table 15B. *Contd.*

LAKE	Macrofaunal Species		r value with Physicochemical parameters and macrofaunal species							
			Hard	TDS	Tur	Cl	PO ₄	NO ₂	NO ₃	Amon
S A R O V A R	Hemiptera	Da	—	—	—	—	.5117*	—	—	—
		Dr	—	—	—	-.4410*	—	—	.7039**	-.4224*
		Ps	—	—	—	—	—	—	—	-.4047*
		Rs	—	-.5458**	-.4239*	—	-.4995*	-.4334*	—	—
	Coleoptera	Hs	.4641*	—	—	—	—	—	—	—
	Diptera	Cs	—	-.4523*	—	—	—	-.4132*	.6647**	-.5908**
	Gastropoda	Bb	.4315*	—	—	.5001***	-.4521*	—	—	—
		Go	.7208**	—	—	.5953**	—	—	-.5524**	—
		Dc	—	—	—	-.6478**	—	—	.7978**	-.5900**
		Tg	—	—	—	—	-.4881*	—	.4303*	—
		Tt	—	.5591**	.5338**	—	—	—	—	—
		Brc	-.4827*	.5915**	.4252*	—	.7306**	.6685**	—	.4848*
		Gl	—	—	—	—	-.7474**	-.4524*	—	—
	Bivalvia	Pc	—	—	—	—	—	—	—	—
	Pisces	Gg	—	-.6171**	—	-.4257*	—	-.4383*	—	-.4863*

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

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cerameopoma (Dc), *Thiara granifera* (Tg), *Thiara tuberculata* (Tt), *Brotia costula* (Brc) and *Gyraulus labiatus* (Gl). In RS, Bb shows positive correlation with DO and NO_3 , no correlation with BOD, COD, pH, Hard and Tur whereas negative correlation with 10 other parameters. In SS, Hard and Cl possess a positive relationship, while only PO_4 shows a negative influence. Similar trend is shown both in terms of species abundance and biomass. Abundance and biomass of Go exhibit negative relationship with Wt, FCO_2 , Tur, PO_4 , NO_2 and Amon in RS. In SS it shows direct relationship with At, BOD, FCO_2 , TA, Con, Hard and Cl whereas negative with NO_3 only. Abundance of Dc shows positive relationship with NO_2 and Amon in RS and also with two factors (DO and NO_3) in SS. The negative relationship shows significant association with Hard in RS and with At, Wt, BOD, FCO_2 , pH, TA, Con, Cl and Amon in SS. Biomass shows the same trend for these parameters while indicating negative r-value also for Hard in RS. DO and NO_3 has positive impact on abundance and biomass of Tg population in RS and only with NO_3 in SS. Negative impact is shown with At, Wt, FCO_2 , TDS, Tur, Cl, PO_4 , NO_2 and Amon in RS whereas only with FCO_2 and PO_4 in SS. Apart from these parameters BOD and TA exhibit negative r value with biomass of Tg. Abundance and biomass of Tt have shown positive relation with COD in RS and with TDS and Tur in SS. Again abundance of Tt exhibits negative relation with five parameters (FCO_2 , TA, Tur, PO_4 and NO_2) and biomass also with five parameters (FCO_2 , TA, Tur, PO_4 and NO_2). Brc expresses positive relationship with DO and NO_3 , no relation with COD, Tur, NO_2 and Amon and negative relationship with others in RS both in terms of abundance and biomass. In SS five parameters viz., Wt, TDS, Tur, PO_4 , NO_2 and Amon have positive effect on abundance and biomass of Brc whereas negative effect is established with BOD and Hard only. Besides, COD also has negative influence on biomass of Brc in SS.

Gl is positively influenced by NO_3 in RS and DO in both the lakes. Wt, PO_4 and NO_2 exhibit negative relationship in both the lakes whereas At, BOD, FCO_2 , TA, Con, TDS, Tur, Cl and Amon express negative relationship in RS.

Bivalvia is represented by a single dominant species i.e. *Pisidium clarkeanum* (Pc) which shows positive r value with FCO_2 and Hard whereas negative r value with Tur and NO_2 in RS. In SS abundance of Pc exhibits only the positive correlation with BOD, TA, Con and Hard. On the other hand, biomass of Pc found to be directly correlated only with DO.

Glossogobius giuris (Gg) is the sole representative of Pisces which is more or less frequently associated with weeds in both the lakes. Positive r-value is found only with Hard in RS, negative relationship with Tur and PO_4 in RS, with TDS and Cl in SS and with NO_2 and Amon in both the lakes.

D. Correlation between macrophyte biomass (gm/m^2) and macrofaunal abundance (no/m^2)

The correlation result of the above biological parameters is summarised in Table 16. To calculate the r-value with different macrofaunal groups as well as total macrofauna, four categories of macrophytes viz., Floating, Submerged, Emergent, Marginal and their

Table 16. Correlation Coefficient (r value) between wet weight and dry weight biomass of macrophyte and macrofaunal component (no/m²) in RS and SS.

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LAKE	Macrophyte Category and Species	r value with total Physicochemical parameters and macrofaunal species												
		T.Macf	Oli	Hir	Crus	Eph	Odo	Hem	Col	Dip	T.Ins	Gas	Biv	Pis
RABINDRASARAROVAR	T. Mac-w	.7136**	-.7490**	.4083*	.4461*	—	—	—	-.4073*	—	—	.7214**	—	—
	T.Mac-d	.5845**	-.6434**	—	—	—	—	—	—	—	—	.5914**	—	—
	Fm-w	—	.4494*	—	—	—	—	—	.6327**	-.4112*	—	—	—	—
	Fm-d	—	.4582*	—	—	—	—	—	.6226**	-.4074*	—	—	—	—
	Sm-w	.7791**	-.8296**	.4241*	.4384*	—	—	—	-.6147**	.4725*	—	.7881**	—	—
	Sm-d	.7516**	-.8312**	.4401*	.4426*	—	—	—	-.6053**	.4701*	—	.7601**	—	—
	Em-w	-.5786**	.6470**	—	—	—	—	—	.8855**	—	—	-.5892**	-.4343*	—
	Em-d	-.5963**	.6639**	—	—	—	—	—	.8782**	-.4176*	—	-.6060**	-.4442*	—
	Mm-w	-.8024**	.7054**	—	—	-.4351*	—	—	.8172**	-.4921*	—	-.8114**	-.4186*	—
	Mm-d	-.7993**	.7310**	—	—	-.4182*	—	—	.8207**	-.5075*	—	-.8114**	-.4186*	—
	Ei-d	—	.4250*	—	—	—	—	—	.6086**	—	—	—	-.4177*	—
	Pi-d	—	.4282*	—	—	—	-.4450*	—	.5262**	-.4343*	—	—	—	—
	Cer-d	.7116**	-.6846**	—	—	.4790*	—	—	-.4475*	—	—	.7237**	—	—
	Val-d	—	-.4758*	.5826**	—	—	.4412*	—	-.4439*	—	—	—	—	—
	Alt-d	-.5688**	.6419**	—	—	—	—	—	-.8795**	—	—	-.5790**	-.4275*	—
	Lud-d	-.7848**	.7024**	—	—	.4360**	—	—	.8276**	-.4706*	—	-.7937**	-.446*	—
SUBHAS	T.Mac-w	.5381**	-.4916*	—	—	—	—	—	—	—	—	.5281**	.4407*	—
	T.Mac-d	.5610**	-.5521**	—	—	.5114*	—	—	—	—	.4070*	.5214**	—	—
	Fm-w	—	—	—	—	—	—	—	.5331**	—	.4382*	—	—	—
	Fm-d	—	—	—	—	—	—	—	.5271**	.4142*	.5177**	—	—	—
	Sm-w	.6026**	-.6221**	—	—	.5384**	—	-.4273*	—	—	.4085*	.5622**	—	—
	Sm-d	.6262**	-.6218**	—	—	.5166**	—	—	—	—	.4219*	.5825**	—	—
	Em-w	-.5392**	.5486**	—	—	—	-.4151*	—	—	-.4092*	-.5103*	.4174*	—	—
	Em-d	-.5365**	.5478**	—	—	—	-.4062*	—	—	-.4139*	.5144*	-.4682*	—	—
	Mm-w	-.6089**	.6696**	—	—	—	—	.4141*	—	—	—	-.5721**	—	—

Table 16. *Contd.*

LAKE	Macrophyte Category and Species	r value with total Physicochemical parameters and macrofaunal species												
		T.Macf	Oli	Hir	Crus	Eph	Odo	Hem	Col	Dip	T.Ins	Gas	Biv	Pis
S A R O V A R	Mm-d	-.6080**	.6731**	—	—	-.4106*	—	.4597*	—	—	—	-.5723**	—	—
	Ei-d	—	—	—	—	—	—	—	.5431**	—	.4847*	—	—	—
	Pi-d	—	—	—	—	—	—	.6157**	—	—	—	—	—	—
	Val-d	.6147**	-.5941**	—	—	.5108*	—	—	—	—	.4206*	.5722**	—	—
	Alt-d	-.5380**	.54689**	—	—	—	-.4159*	—	—	-.4090*	-.5099*	-.4702*	—	—
	Lud-d	-.6321**	.6726**	—	—	—	—	.4804*	—	—	—	-.5971**	—	—

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

w = Wet weight biomass

d = Dry weight biomass

For full name of abbreviation vide list of abbreviation

cumulative value as, 'Total macrophytes' has been selected and measured as wet weight as well as dry weight. Apart from these, the most dominant macrophyte species belonging to the genera, *Eichhornia*, *Pistia*, *Vallisneria*, *Alternanthera* and *Ludwigia* from both the lakes along with a species of *Ceratophyllum* from RS have been brought under the present investigation. Only dry weight that is the actual weight of the plant is measured for the selected macrophyte species.

It is evident from the result that total macrophyte biomass shows positive correlation with the abundance of total macrofauna and with three macrofaunal groups. The highest significant result is shown by gastropods ($r = 0.7214^{**}$) in RS and in SS with Total macrofauna and Gastropoda. Besides these, Bivalvia shows positive correlation with wet weight biomass and Ephemeroptera and total insect with dry weight biomass of total macrophytes. Among the different categories of macrophytes, the submerged macrophytes (dry weight and wet weight) show maximum number of positive r-value with Total macrofauna, Hirudinea, Crustacea, Diptera and Gastropoda in RS. The highest r-value (0.7881^{**}) is also observed with Gastropoda, which is the most dominant group. In SS, among the different macrophyte categories, submerged macrophytes (wet weight) show groupwise highest number of significant r-value i.e. with five macrofaunal groups viz., Oligochaeta, Ephemeroptera, Hemiptera, Total Insecta and Gastropoda whereas highest positive r-value with Total macrofauna ($r = 0.6262^{**}$). Among the different macrophyte species, *Ceratophyllum* and *Ludwigia* in RS (both shows positive r value with three macrofaunal group) and *Vallisneria* in SS (shows positive r value with four macrofaunal groups) establish as major controlling factor.

E. Correlation between macrophyte biomass (gm/m^2) and macrofaunal biomass (gm/m^2)

Result presented in Table 17 reveals that total macrophyte biomass shows highest r value ($r = 0.6966^{**}$) with total macrofauna in RS, but in SS only Ephemeroptera shows the positive relationship. In RS submerged macrophyte shows positive relation with total macrofauna and five macrofaunal groups. In SS, both submerged and marginal macrophyte express positive correlation with a single macrofaunal group viz., Ephemeroptera and Hemiptera respectively, but negative with others. Among different macrophyte species, the highest r-value (0.5814^{**}) is observed between *Ceratophyllum* and Gastropoda in RS, while in SS the highest r-value (0.6013^{**}) is shown between *Eichhornia* and Coleoptera expressing there general preference towards that macrophytes for taking shelter and feeding or egg laying purposes respectively.

F. Correlation between macrophyte biomass (gm/m^2) and macrofaunal species abundance (no/m^2) as well as biomass (gm/m^2)

For this purpose 20 macrofaunal species belonging to Oligochaeta (1 species), Crustacea (2 species), Odonata (2 species), Hemiptera (5 species), Coleoptera (1 species), Diptera (1 species), Gastropoda (7 species), Bivalvia (1 species) and Pisces (1 species) have been selected and the results are presented in Table 18 for RS and in Table 19 for SS.

Table 17. Correlation Coefficient (r value) between wet weight and dry weight biomass of macrophyte and macrofaunal biomass (gm/m²) in RS and SS.

LAKE	Macrophyte Category and Species	r value with total Physicochemical parameters and macrofaunal species												
		T.Macf	Oli	Hir	Crus	Eph	Odo	Hem	Col	Dip	T.Ins	Gas	Biv	Pis
RABINDRA SARA ROVAR	T. Mac-w	.6966**	-.8032**	.4642*	.5489**	—	—	—	—	.5777**	—	.6957**	—	—
	T.Mac-d	.6130**	-.7296**	—	.5028*	—	—	—	—	.5044*	—	.6108**	—	—
	Fm-w	—	—	—	—	—	—	—	.6740**	—	—	—	-.4266*	—
	Fm-d	—	—	—	—	—	—	—	.6647**	—	—	—	-.4188*	—
	Sm-w	.7156**	-.8158**	.5057*	.5654*	—	—	—	-.5965**	.6422*	—	.7154**	—	.4256*
	Sm-d	.7051**	-.8219**	.4899*	.5703**	—	—	—	-.5804**	.6419**	—	.7043**	—	.4368*
	Em-w	-.4833*	.5342**	—	—	—	—	.6870**	.7475**	-.4424*	.5605**	-.4909*	-.4507*	—
	Em-d	-.5011**	.5439**	—	—	—	—	.6674**	.7506**	-.4612*	.5355**	-.5080*	-.4569*	—
	Mm-w	-.6396**	.6228**	-.4187*	-.4562*	-.4527*	—	.4565*	.6370**	-.6179*	—	-.6421**	-.4397*	-.4911*
	Mm-d	-.6479**	.6765**	-.4402*	-.4800*	-.4487*	—	.4550*	.6602**	-.6315**	—	-.6493**	-.4138*	-.5374*
	Ei-d	—	—	—	—	—	—	—	.6518*	—	—	—	-.4184*	—
	Pi-d	—	—	—	—	—	—	—	.5556**	—	—	—	—	-.5578**
	Cer-d	.5714**	-.7067**	—	.4455*	.4429*	—	—	-.4324*	—	—	.5814**	—	—
	Val-d	.4270*	-.4118*	.5907**	—	—	—	—	-.4226*	—	—	.4250*	—	—
SHASS	Alt-d	-.4743*	.5243**	—	—	—	—	.6879**	-.7498**	-.4360*	.5638**	-.4817*	-.4471*	—
	Lud-d	-.6360**	.6634**	-.4286*	-.4412*	-.4515*	—	.4695*	.6464**	-.6044*	—	-.6897**	-.4395*	-.4803*
	T.Mac-w	—	-.4291*	—	—	—	—	—	—	—	—	—	—	—
	T.Mac-d	—	-.4217*	—	—	.4931*	—	—	—	—	—	—	—	—
	Fm-w	—	—	—	—	—	—	—	.6109**	.4075*	.4405*	—	—	—
	Fm-d	—	—	—	—	—	—	—	.5679**	—	.4508*	—	—	—
	Sm-w	—	-.4401*	—	—	.5315**	—	-.4151*	—	—	—	—	—	—
	Sm-d	—	—	—	—	.5072*	—	—	—	—	—	—	—	—
	Em-w	—	—	—	—	—	-.5507**	—	—	—	—	—	—	—
	Em-d	—	—	—	—	—	-.5458**	—	—	—	—	—	-.4434*	—
	Mm-w	—	—	—	—	-.4480*	—	.5389*	—	—	—	-.4645**	—	—

Table 17. *Contd.*

LAKE	Macrophyte Category and Species	r value with total Physicochemical parameters and macrofaunal species												
		T.Macf	Oli	Hir	Crus	Eph	Odo	Hem	Col	Dip	T.Ins	Gas	Biv	Pis
S A R O V A R	Mm-d	-.4425*	—	—	—	-.4529*	—	.5403**	—	—	—	-.4534*	—	—
	Ei-d	—	—	—	—	—	—	—	.6013**	—	.4055*	—	—	—
	Pi-d	—	—	—	—	—	—	.4284*	—	—	—	—	—	—
	Val-d	—	-.4192*	—	—	.4972*	—	—	—	—	—	—	—	—
	Alt-d	—	—	—	—	—	-.5507**	—	—	—	—	—	-.4424*	—
	Lud-d	-.4772*	—	—	—	—	—	.5524*	—	—	—	-.4864*	—	—

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

w = Wet weight biomass

d = Dry weight biomass

For full name of abbreviation vide list of abbreviation

Table 18. Correlation Coefficient(r value)between biomass of macrophytes (gm/m²) and abundance of macrofaunal species (no/m²) in RS and SS.

LAKE	Macrophyte Category and Species	r value between macrophyte biomass and macrofaunal species abundance																			
		Lh	Md	Pm	Bc	Da	Dr	Ps	Rs	Hs	Chr	Bb	Go	Dc	Tg	Tt	Brc	Gl	Pc	Gg	
RABINDRA SAROVAR	T.Mac-w	-.82*	.43*	—	-.41*	—	—	—	—	—	.41*	.48*	.73**	—	.80**	.43*	.54**	.69**	—	.45*	
	T.Mac-d	-.76	—	—	-.41*	—	—	—	—	—	—	.41*	.57**	—	.68**	—	.46*	.55**	—	—	
	Fm-w	—	—	-.41**	—	—	—	-.41*	—	.75**	-.41*	—	-.52**	.73**	-.42*	-.40*	—	-.45*	—	-.46*	
	Fm-d	—	—	-.41*	—	—	—	-.41*	—	.74**	-.41*	—	-.52**	.74**	-.42*	—	—	-.45*	—	-.46*	
	Sm-w	-.82**	.43*	—	—	-.43*	—	—	.48*	-.63**	.50*	.56**	.82**	—	.85**	.56**	.52**	.78**	—	.55**	
	Sm-d	-.85**	.42*	—	—	-.43*	—	—	.50*	-.61**	.49*	.58**	.77**	—	.82**	.52**	.49*	.76**	—	.54**	
	Em-w	.52**	—	—	—	.72**	—	-.61**	-.59**	.90**	-.41*	-.59**	-.56**	.48*	-.49*	-.76**	—	-.64**	-.45*	-.46*	
	Em-d	.54**	—	—	—	.71**	—	-.62**	-.60**	.90**	-.43*	-.59**	-.57**	.47*	-.51*	-.77**	—	-.66**	-.45*	-.47*	
	Mm-w	.62**	—	—	—	.48*	—	-.43*	-.51*	.81**	-.51*	-.51*	-.76**	—	-.65**	-.82**	-.51**	-.82**	-.44*	-.55**	
	Mm-d	.64**	—	—	—	.49*	—	-.45*	-.54**	.83**	-.53**	-.54**	-.75**	—	-.66**	-.79**	-.52**	-.81**	—	-.56**	
	Ei-d	—	—	—	—	—	—	-.48*	-.42*	.75**	—	—	-.50*	.59**	-.42*	-.49*	—	-.49*	-.41*	—	
	Pi-d	—	—	-.50*	—	—	—	—	—	.54**	-.43*	—	-.45*	.90**	—	—	—	—	—	-.49*	
	Cer-d	-.70**	—	—	—	-.52**	—	—	—	-.44*	—	—	.89**	—	.85**	.49*	—	.75**	—	.62**	
	Val-d	-.49*	—	—	—	—	.49*	.55**	.41*	-.49*	—	.73**	—	—	—	—	—	—	—	—	
	Alt-d	.51*	—	—	—	.73**	—	-.61**	-.60**	.89**	-.41*	-.58**	-.55**	.49*	-.48*	-.75**	—	-.63**	-.45*	-.45*	
	Lud-d	.61**	—	—	—	.49*	—	-.45*	-.51**	.83**	-.48*	-.51*	-.74**	—	-.64**	-.82**	-.51*	-.81**	-.45*	-.55**	
SUBHAS	T.Mac-w	-.50*	—	—	.49*	-.53**	—	—	.46*	—	—	.50*	.63**	—	—	—	-.44*	.52**	.41*	—	
	T.Mac-d	-.55**	—	—	.41*	-.62**	—	—	.47*	—	—	.60**	.60**	—	—	—	-.61**	.67**	—	—	
	Fm-w	—	—	—	—	—	—	.45*	.47*	.64**	.40*	—	—	—	—	—	—	.49**	—	—	
	Fm-d	—	—	—	—	-.48*	—	.46*	—	.63**	.42*	—	—	—	—	—	-.49*	.59**	—	—	
	Sm-w	-.63**	—	—	.43*	—	—	—	.41*	—	—	.64**	.63**	—	—	—	-.66**	.74**	—	—	
	Sm-d	-.63**	—	—	.42*	—	—	—	.49*	—	—	.66**	.59**	—	—	—	-.63**	.73**	—	—	
	Em-w	.55**	—	-.41*	-.46*	.77**	—	—	.48*	—	—	-.45*	-.49*	—	—	—	.56**	—	—	—	
	Em-d	.55**	—	-.41*	-.46*	.78**	—	—	-.47*	—	-.41*	-.46*	-.50*	—	—	—	.57**	—	—	—	
	Mm-w	.71**	—	—	—	.70**	—	—	-.48*	—	—	-.63**	—	—	—	—	.61**	.69**	—	—	
Mm-d	.71**	—	—	—	.66**	—	—	—	—	—	-.63**	—	—	—	—	.62**	-.69**	—	—		

Table 18. *Contd.*

LAKE	Macrophyte Category and Species	r value between macrophyte biomass and macrofaunal species abundance																		
		Lh	Md	Pm	Bc	Da	Dr	Ps	Rs	Hs	Chr	Bb	Go	Dc	Tg	Tt	Brc	Gl	Pc	Gg
SAROVAR	Ei-d	—	—	—	—	-.49*	—	.43*	.41*	.66*	—	—	—	—	—	—	—	.55**	—	—
	Pi-d	—	—	—	—	.72**	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Val-d	.60**	—	—	.42*	—	—	—	—	—	—	.64**	.61**	—	—	—	-.62**	.69**	—	—
	Alt-d	.55**	—	-.41*	-.46*	.78**	—	—	.48*	—	—	-.45*	-.49*	—	—	—	.56**	-.73**	—	—
	Lud-d	.70**	—	—	—	.68**	—	—	-.47*	—	—	-.65**	—	—	—	—	.58**	-.67**	—	—

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

w = Wet weight biomass

d = Dry weight biomass

MI fails to form any significant correlation

Table 19. Correlation Coefficient (r value) between macrophytal biomass (gm/m²) and specieswise macrofaunal biomass (gm/m²) in RS and SS.

LAKE	Macrophyte Category and Species	r value between macrophyte biomass and macrofaunal species abundance																			
		Lh	Md	Pm	Bc	Da	Dr	Ps	Rs	Hs	Chr	Bb	Go	Dc	Tg	Tt	Brc	Gl	Pc	Gg	
RABINDRASAROVAR	T.Mac-w	-.83*	.43*	—	-.41*	—	—	—	—	-.42*	.48*	.48*	.72**	—	.79**	.61**	.53**	.70**	—	.45*	
	T.Mac-d	-.77**	—	—	-.41*	—	—	—	—	—	.44*	.42*	.56**	—	.67**	.42*	.45*	.55**	—	—	
	Fm-w	—	—	—	—	—	—	-.50*	—	.74**	—	—	-.52**	.79**	-.43*	-.49*	—	-.46*	—	-.45*	
	Fm-d	—	—	—	—	—	—	—	—	.73**	—	—	-.52**	.80**	-.43*	-.47*	—	-.46*	—	-.46*	
	Sm-w	-.85**	.43*	—	—	-.43*	—	—	—	-.65**	.40*	.57**	.81**	—	.85**	.74**	.50*	.79**	—	.55**	
	Sm-d	-.87**	.42*	—	—	-.43*	—	-.63**	.41*	-.65**	.46*	.59**	.76**	—	.81**	.69**	.47*	.76**	—	.55**	
	Em-w	.54**	—	—	—	.72**	—	-.63**	-.48**	.87**	—	-.59**	-.57**	.61**	-.51*	-.79**	—	-.65**	-.45*	-.45*	
	Em-d	.55**	—	—	—	.70**	—	-.44*	-.49*	.87**	—	-.60**	-.58**	.59**	-.53**	-.77**	—	-.67**	-.45*	-.46*	
	Mm-w	.65**	—	—	—	.49*	—	-.45*	-.41*	.78**	—	-.52**	-.77**	.44*	-.68**	-.84**	-.51*	-.83**	-.44*	-.53**	
	Mm-d	.67**	—	—	—	.49*	—	-.54**	-.46*	.81**	—	-.55**	-.76**	.46*	-.69**	-.81**	-.52**	-.82**	—	-.55**	
	Ei-d	—	—	—	—	—	—	—	-.41*	.72**	—	—	-.50*	.71**	-.43*	-.54*	—	-.49*	-.41*	—	
	Pi-d	—	—	-.47*	—	—	—	—	—	.58**	—	—	-.44*	.81**	—	—	—	—	—	-.50*	
	Cer-d	-.73**	—	—	-.51**	—	—	—	—	.44**	.62**	—	.89**	—	.83**	.74*	—	.75**	—	.62**	
	Val-d	-.46*	—	.43*	—	—	.60**	-.63**	—	-.56**	—	.75**	—	—	—	—	—	—	—	—	
	Alt-d	.53**	—	—	—	.72**	—	-.46*	-.48*	.87**	—	-.59**	-.56**	.61**	-.50*	-.77**	—	-.64**	-.44*	-.44*	
	Lud-d	.65**	—	—	—	.49*	—	—	-.42*	.79**	—	-.52**	-.75**	.45*	-.67**	-.83**	-.50*	-.82**	-.46*	-.54**	
SUBHAS	T.Mac-w	—	—	—	.48*	-.53**	—	—	.46*	—	—	.51*	.63**	—	—	—	-.47*	.52**	—	—	
	T.Mac-d	-.44**	—	—	—	-.62**	—	—	.47*	—	—	.60**	.60**	—	—	—	-.63**	.66**	—	—	
	Fm-w	—	—	—	—	—	—	—	—	.65**	—	—	—	—	—	—	—	.53**	—	—	
	Fm-d	—	—	—	—	-.47*	—	—	—	.64**	.42*	—	—	—	—	—	-.48*	.61**	—	—	
	Sm-w	-.50*	.47*	—	.42*	-.69**	—	—	.49*	—	—	.64**	.62**	—	—	—	-.68**	.73**	—	—	
	Sm-d	-.51*	.47*	—	.41*	-.66**	—	—	.48*	—	—	.66**	.59**	—	—	—	-.64**	.72**	—	—	
	Em-w	.51*	—	-.43*	-.45*	.77**	—	—	-.47*	-.47*	-.41*	-.46*	-.49*	—	—	—	.58**	-.73**	-.43*	—	
	Em-d	—	—	—	—	.47*	—	—	—	.64**	.42*	—	—	—	—	—	.48*	.61**	—	—	
	Mm-w	.56**	—	—	—	.68**	—	—	-.40*	—	—	-.63**	—	—	—	—	.59**	-.69**	—	—	
	Mm-d	.56**	—	—	—	.68**	—	—	-.41*	—	—	-.63**	—	—	—	—	.61**	-.69**	—	—	

Table 19. *Contd.*

LAKE	Macrophyte Category and Species	r value between macrophyte biomass and macrofaunal species abundance																		
		Lh	Md	Pm	Bc	Da	Dr	Ps	Rs	Hs	Chr	Bb	Go	Dc	Tg	Tt	Brc	Gl	Pc	Gg
SAROVAR	Ei-d	—	—	—	—	-.48*	—	—	—	.67**	—	—	—	—	—	—	—	.58**	—	—
	Pi-d	—	—	—	—	.71**	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Val-d	-.48*	—	—	.42*	—	—	—	.48*	—	—	.64**	.60**	—	—	—	-.64**	.69**	—	—
	Alt-d	.51*	—	-.44*	.46*	.77**	—	—	-.46*	-.47*	-.41*	-.45*	-.48*	—	—	—	.57**	.72**	-.42*	—
	Lud-d	.55**	—	—	—	.67**	—	—	—	—	—	-.65**	—	—	—	—	.57**	-.67**	—	—

Note : * = Significant at 5% level of significance

** = Significant at 1% level of significance

w = Wet weight biomass

d = Dry weight biomass

MI fails to form any significant correlation

From the result it is evident that *Gabbia orcula* is ranked at the top, if total macrophyte association is taken into consideration ($r = 0.7310^{**}$ for species abundance and $r = 0.7208^{**}$ for species biomass). For species abundance, the highest correlation ($r = 0.9007^{**}$) is shown between the *Hydrocoptus subvittulus* and emergent macrophyte in RS and in SS between *Diplonychus annulatus* and emergent macrophyte ($r = 0.7767^{**}$). Species biomass also shows the similar trend. Correlation values of the individual macrophyte species and macrofaunal species have revealed highest correlation between *Ceratophyllum* and *Thiara granifera* ($r = 0.8513^{**}$) for abundance and between *Ceratophyllum* and *Gabbia orcula* ($r = 0.8881^{**}$) for biomass in RS. But in SS this relationship relates to *Alternanthera* and *Diplonychus annulatus* for abundance ($r = 0.7709^{**}$) as well as biomass ($r = 0.7699^{**}$).

4.9.3. Stepwise multiple regression analysis

Stepwise multiple regression technique is adopted to study which of the physicochemical parameters/macrophytes affects the abundance as well as biomass of total macrofauna, macrofaunal groups or the regularly occurring macrofaunal species. Partial regression coefficient (β_j), constant value (β_0), their respective standard errors and coefficient of determination (R^2); corresponding each independent variable i.e. physicochemical parameters or biomass of different macrophyte categories and species are presented in Table 20 to Table 33. The β_0 and β_j help to form the multiple regression equation. The partial regression coefficients determine the expected change in density or biomass of the macrofaunal groups/species caused by the unit increase or decrease of the corresponding independent variable, if other variables remaining unchanged. The R^2 values for total macrofauna/groups/species measures the percentage of variation for the corresponding independent variables (Table 20 to Table 33).

A. Multiple regression analysis between physicochemical parameters and abundance (no/m²) of total macrofauna as well as groups.

Results of multiple regression analysis are presented in Table 20 for RS and Table 21 for SS. It is evident that the highest R^2 value 0.9228^{**} is shown by Total macrofauna in RS. Furthermore, BOD, DO, NO_2 , NO_3 , PO_4 are found to be important factor affecting the total macrofaunal density and jointly explains 92% variation in RS. Among the five corresponding partial regression coefficient, besides NO_3 all the parameters show negative β_j values. If these parameters have no influence, the density of Total macrofauna will be exorbitantly high (3963/m²). However, in SS only Amon and PO_4 bear a relationship with Total macrofauna and 40% variation can be explained their density. If these two parameters have no influence, the density will be as high as 1259/m². Negative sign of β_j value for PO_4 indicates the fall in macrofaunal abundance (1315/m²) for unit increase of corresponding variables. For other macrofaunal groups like Oligochaeta, Hirudinea, Crustacea, Ephemeroptera, Odonata, Hemiptera, Total Insects, Gastropoda, Bivalvia and Pisces result can be explained in similar way as explained in case of Total macrofauna. The number of independent variables involves in the formation of multiple regression equation of the above mentioned groups, ranges from one to five.

Table 20. Stepwise multiple regression analysis between physiochemical parameters and biological parameters in terms of abundance (no/m²) in RS.

Biological Parameters	Physico Chemical Parameter	Multiple regression values between Physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Total Macrofauna	BOD	-93.4851*	38.2620	3963.52**	500.42	0.9228**
	DO	-344.0655**	88.0139			
	NO ₂	-3054.1554**	458.5642			
	NO ₃	2449.0535**	503.6725			
	PO ₄	-1170.3959**	199.3605			
Oligochaeta	Amon	43.7604*	16.8799	-2.4630	4.6182	0.6095**
	PO ₄	26.0691	7.0699			
Hirudinea	NO ₃	5.4167**	0.9933	-1.8009**	0.5871	0.5748**
Crustacea	At	-4.9067**	0.6974	201.18**	20.14	0.6923**
Total Insects	Do	19.0648**	3.8339	-112.22**	32.6304	0.5581**
	Tur	1.8036**	0.6196			
Odonata	Cl	0.3488**	0.1038	31.3384**	9.4397	0.6956**
	Tur	0.9957**	0.1707			
Hemiptera	Wt	-1.9164**	0.4509	-62.7535*	27.0007	0.3292*
	Amon	72.6512*	34.8899			
	DO	9.6337**	3.6609			
Coleoptera	NO ₂	9.9296**	1.7828	-2.2431	1.3597	0.7079**
	Wt	0.1377	0.0493			
Diptera	Wt	-2.6719**	0.4931	85.9013**	14.0839	0.5716**
Gastropoda	BOD	-84.8931*	38.3019	3861.69**	500.9427	0.9196**
	DO	-356.7151**	88.1057			
	NO ₂	-3112.4831**	459.0422			
	NO ₃	2441.4018**	504.1975			
	PO ₄	-1159.9291**	199.5683			
Bivalvia	NO ₂	-23.8242*	11.3782	15.8496**	3.3731	0.3987
	Tur	0.3672*	0.1677			
Pisces	TDS	-0.3474*	0.0126	11.86978**	3.0650	

Note : β_j = Partial regression coefficient, β_0 = Constant, SE = Standard error, R² = Coefficient of determination, * = Significant at 5% level of significance, ** = Significant at 1% level of significance. For full name of abbreviation vide list of abbreviation.

Table 21. Stepwise multiple regression analysis between physiochemical parameters and biological parameters in terms of abundance (no/m²) in RS.

Biological Parameters	physico Chemical Parameter	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Total Macrofauna	Amon	1314.6124*	485.3057	1258.6915**	126.0174	0.4021**
	PO ₄	-897.2584**	249.6628			
Oligochaeta	PO ₄	67.6259**	11.7986	17.8683**	5.3502	0.5989**
Hirudinea	At	-6.0130**	0.9729	186.6089**	28.3650	0.6345**
Crustacea	Do	15.1971**	4.9284	37.2182	44.8971	0.4947**
	Hard	-1.0087*	0.4046			
Arachnida	pH	-5.4390**	1.8539	46.8547**	14.9465	0.2812**
Total Insects	pH	39.9130*	17.9522	261.6521*	127.9555	0.7111**
	Wt	-17.4359**	2.4616			
Ephemeroptera	PO ₄	-5.2192**	1.4081	12.4170**	1.5814	0.6786**
	Tur	-0.3921**	0.0745			
Odonata	Amon	41.3643*	15.4928	5.8723	4.5396	0.2447*
Hemiptera	BOD	-1.7407*	0.6796	27.4044**	5.8478	0.2297*
Coleoptera	BOD	-2.6209*	1.1912	-58.2486**	14.9267	0.7269**
	Cl	-0.8082**	0.2138			
	Hard	1.0297**	0.1891			
Diptera	Con	0.1556**	0.0397	485.9919**	56.2943	0.7957**
	At	11.9916*	4.8251			
	Con	-0.3603**	0.1170			
	Wt	-22.7399**	4.6144			
Bivalvia	Hard	0.4091**	0.1325	-19.1841*	8.5923	0.3024**
Pisces	BOD	-0.6953**	0.2039	5.5267	3.1295	0.7593**
	COD	0.1015**	0.0347			
	Con	0.0284**	0.0074			
	TDS	-0.0624**	0.0131			

Note : β_j = Partial regression coefficient, β_0 = Constant, SE = Standard error, R² = Coefficient of determination, * = Significant at 5% level of significance, ** = Significant at 1% level of significance. For full name of abbreviation vide list of abbreviation.

B. Multiple regression analysis between physicochemical parameters and biomass (gm/m²) of total macrofauna and as well as groups

Results of the above mentioned multiple regression analysis are shown in Tables 22 and 23. In RS, the highest R² value relates to Total macrofauna (0.9367**) followed by Gastropoda (0.9291**) and Crustacea (0.9110**). It is interesting to note that for all three above mentioned groups NO₃ is the common factor and presenting positive β_j values. The number of physicochemical factors controlling the different macrofaunal groups ranges from one to five. In SS, the R² value shown for Hirudinea (0.8334**) by Amon, COD, NO₃ and Con is followed by Diptera (0.8173**) and Pisces (0.5694**). The number of independent variables controlling the dependent variables herein ranges from one to four.

C. Multiple regression analysis between physicochemical parameters and abundance of dominant macrofaunal species

Results are presented in Tables 24 and 25. The density of *Limnodrilus hoffmeisteri*, an oligochaete species found to be influenced by NO₃, pH and PO₄ in RS and only by PO₄ in SS. In RS, three independent factors cause 79% variation whereas PO₄ independently control 69% variation in SS. Among the factors, PO₄ is most important as it shows positive β_j values 22.8682** and 46.9521** for RS and SS respectively. Results for other 19 regularly occurring species can be explained in the similar way. Number of independent variables influencing the abundance of these 19 species ranges from one to five in RS and one to four in SS.

D. Multiple regression analysis between physicochemical parameters and biomass of dominant macrofaunal species

To study this aspect, biomass of 20 dominant/regularly occurring macrofaunal species are subjected to regression analysis along with 17 physicochemical parameters and the result are presented in Tables 26 and 27. The number of physicochemical factors controlling the variation in biomass of different regularly occurring species in RS and SS ranges from one to five. Biomass of Md, Ml, Pm, Da, Ps, Rs in Rabindra Sarovar and that of Md, Ml, Bc, Dc, Tg, Gl and Gg in SS appear to be controlled by a single independent variable although variables differ for each species. Biomass of Hs, Go, Tt, Pc in RS and of Cs, Bb, Go, Tt and Brc in SS are evidently influenced by two independent variables that differ from one to another species. Macrofaunal species biomass is controlled by three independent variables for Bb, Dc, Tg and Brc in RS and for Ps and Pc in SS. Species biomass explained jointly by four independent variables relates to Bc and Dr in RS and Hs only in SS. Besides, biomass of Gg in RS is controlled simultaneously by five physicochemical parameters and explains 87% variability.

E. Multiple regression analysis between macrophyte biomass and macrofaunal components in terms of abundance (no/m²) as well as biomass (gm/m²) in Rabindra Sarovar

The result is presented in Table 28. It is evident that wet weight biomass of total macrophyte and that of marginal macrophyte influence the abundance of total macrofauna.

Table 22. Stepwise multiple regression analysis between physicochemical parameters and biological parameters in terms of Biomass (gm/m²) in RS.

Biological Parameters	physico Chemical Parameter	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Total Macrofauna	DO	-74.0562**	8.9475	584.8977**	63.9950	0.9367**
	FCO ₂	-84.9343**	151439			
	NO ₂	-156.2782**	45.7355	0.0017**	0.0003	0.5996**
	NO ₃	392.9214**	46.1292			
Oligochaeta	PO ₄	0.0044**	0.0008	0.0846	0.0917	0.7156**
Hirudinea	NO ₃	0.2396**	0.0501			
	TA	-0.0004*	0.0002	14.9677**	2.9923	0.9110**
Crustacea	NO ₃	6.9139**	1.4322			
	Wt	-0.4277**	0.0830	5.0054**	1.3463	0.2235*
Total Insects	Hard	-0.0318*	0.0126			
Ephemeroptera	Bod	-0.0014**	0.0003	-0.0101**	0.0023	0.8205**
	Cl	0.0001**	0.0001			
	Hard	0.0001**	0.0001	0.0149	0.0265	0.2559*
	PO ₄	-0.0070**	0.0018			
Odonata	Tur	-0.0030*	0.0011	0.2034	0.3028	0.1761*
Hemiptera	NO ₂	4.1187*	1.8995			
Coleoptera	At	-0.0429*	0.0397	-1.1136**	0.2526	0.8974**
	DO	0.0522**	0.0167			
	NO ₂	0.4019*	0.0163	1.6916**	0.2071	0.7963**
	PO ₄	-0.1206*	0.1521			
	Wt	0.0809**	0.0521	577.9919**	65.2954	0.9291**
Diptera	BOD	0.0969*	0.0960			
	FCO ₂	-1.4511**	0.4723	577.9919**	65.2954	0.9291**
	NO ₂	-74.0777**	9.1294			
Gastoroda	FCO ₂	-82.3101**	15.4512	577.9919**	65.2954	0.9291**
	NO ₂	-157.4984**	46.6650			
	NO ₃	384.2549**	47.0667	577.9919**	65.2954	0.9291**
	NO ₃	-0.6109*	0.2515			
Pisces	Wt	-0.0616**	0.0146	2.3856**	0.5225	0.4812**

Note : β_j = Partial regression coefficient, β_0 = Constant, SE = Standard error, R² = Coefficient of determination, * = Significant at 5% level of significance, ** = Significant at 1% level of significance. For full name of abbreviation vide list of abbreviation.

Table 23. Stepwise multiple regression analysis between physicochemical parameters and biological parameters in terms of biomass (gm/m²) in SS.

Biological Parameters	Physico Chemical Parameters	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Total Macrofauna	PO ₄	-55.9676*	26.6434	114.8926*	45.8537	0.3568**
	TDS	0.9157**	0.2834			
Oligochaeta	BOD	-0.0052*	0.0020	0.1019**	0.0158	0.5227**
	Cl	-0.0007*	0.0003			
Hirudinea	Amon	-0.1630*	0.0696	-0.3727**	0.0843	0.8334**
	COD	-0.0035**	0.0008			
	NO ₃	0.4324**	0.0564			
	Con	0.0009**	0.0002			
Crustacea	Hard	-0.1717*	0.0772	23.2322**	6.1661	0.5077**
	NO ₃	14.1669**	4.9551			
Arachnida	pH	-0.0278**	0.0092	0.2406**	0.0744	0.2927**
Total Insects	BOD	-0.1273*	0.0507	4.7707**	0.8369	0.4575**
	Wt	-0.0781*	0.0289			
Ephemeroptera	PO ₄	-0.0039**	0.0009	0.0086**	0.0011	0.6821**
	Tur	-0.0002**	0.0001			
Odonata	Amon	0.3859**	0.1135	0.3639*	0.1288	0.3548*
	Wt	-0.0124*	0.0051			
Hemiptera	BOD	0.1045**	0.0354	2.7421**	0.5723	0.3512*
	DO	-0.1520	0.0676			
Diptera	DO	0.1547*	0.0639	0.9909	0.9031	0.8173**
	Wt	-0.0609**	0.0191			
Gastoroda	PO ₄	-58.5159*	26.1669	88.2046	45.0335	0.3859**
	TDS	0.9570**	0.2783			
Pisces	At	-0.0626**	0.0119	1.3100**	0.3219	0.5694**
	Con	0.0019**	0.0006			

Note : β_j = Partial regression coefficient, β_0 = Constant, SE = Standard error, R² = Coefficient of determination, * = Significant at 5% level of significance, ** = Significant at 1% level of significance. For full name of abbreviation vide list of abbreviation.

Table 24. Stepwise multiple regression analysis between physicochemical parameters and dominant macrofaunal species in terms of abundance (no/m₂) in RS.

Dominant Macrofaunal Species	physico Chemical Parameters	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Oligochaeta Lh	NO ₃	-17.4389**	4.9291	57.4097**	19.8877	0.7918**
	pH	-5.4849*	2.2531			
	PO ₄	22.8628**	3.5865			
Crustacea Md	At	-3.8148**	0.4426	148.2113**	12.7840	0.7715**
MI	TDS	-0.0752**	0.0213	36.0326**	5.1771	0.3616**
Odonata Pm	Wt	-0.6686**	0.1601	27.0343**	4.57632	0.4421**
Bc	PO ₄	4.6595**	1.8181	-3.7411**	1.2876	0.5957**
	Tur	0.2260**	0.0677			
Hemiptera Da	Hard	-0.1743*	0.0793	23.5499*	8.4323	0.1802*
Dr	NO ₃	6.1140**	1.0486	-1.0855	0.6198	0.6071**
Ps	COD	0.1639*	0.06198	-0.7780	1.8097	0.2424*
Rs	Wt	-0.1281*	0.0323	4.9126**	0.9220	0.4173**
Coleoptera Hs	NO ₂	6.8265**	1.2652	-2.2844*	0.9649	0.7381**
	Wt	0.1340**	0.0350			
Diptera Cs	Wt	-.2.3052**	0.3800	73.5888***	10.8549	0.6258**
Gastropoda Bb	Amon	-556.2846**	118.1101	608.8706**	123.6867	0.7903*
	DO	-91.5421**	24.6451			
	NO ₃	766.4841**	127.1919			
Go	NO ₂	-801.5833*	286.0187	657.3794**	63.5631	0.6163**
	PO ₄	-463.2792**	113.2911			
	Cl	-0.3113**	0.0539			
Dc	NO ₂	32.3238	5.2988	-7.3062	4.2268	0.9255**
	Con	-0.0346	0.0077			
	Tur	-0.2746	0.0753			
	Wt	1.9953	0.2116			

Table 24. Contd.

Dominant Macrofaunal Species	Physico Chemical Parameter	Multiple regression values between Physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Tg	Amon	-216.8913**	77.4605	242.5597**	21.1924	0.6199**
	PO ₄	-131.2570**	32.4432			
Tt	COD	0.5076**	0.2236	76.3784**	14.3313	0.8213**
	NO ₂	-47.1293**	13.3297			
	TA	-0.1387**	0.0256			
Brc	Cl	-0.7211**	0.2062	111.1207**	23.9771	0.8656**
	DO	-16.1591**	4.0462			
	NO ₃	129.7260**	24.9655			
Gl	BOD	-33.3017*	12.1268	1526.0791**	219.5255	0.8805**
	DO	-87.7834**	24.7968			
	FCO ₂	-288.0988**	52.9230			
	NO ₂	-607.6433**	158.5314			
Bivalvia Pc	Hard	0.1547**	0.0308	-4.0753	4.4672	0.5696**
	Wt	-0.3406*	0.1321			
Pisces Gg	At	0.5154**	0.1148	3.0467	1.9848	0.8726**
	NO ₃	-1.8010*	0.8145			
	PO ₄	-2.4591**	0.4737			
	TA	0.0059*	0.0022			
	Wt	-0.5795**	0.0984			

Note : β_j = Partial regression coefficient, β_0 = Constant, SE = Standard error, R² = Coefficient of determination, * = Significant at 5% level of significance, ** = Significant at 1% level of significance. For full name of abbreviation vide list of abbreviation.

Table 25. Stepwise multiple regression analysis between physicochemical parameters and dominant macrofaunal species in terms of abundance (no/m₂) in SS.

Dominant Macrofaunal Species	physico Chemical Parameters	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Oligochaeta Lh	PO ₄	46.9521**	6.6289	9.7736**	3.0060	0.6951**
Crustacea Md	Wt	-3.7729**	0.8800	142.8320**	25.1686	0.4552**
MI	Con	-0.1236*	0.0454	77.9534**	18.4824	0.2517*
Odonata Pm	Amon	25.1922**	6.1429	5.2364	13.0664	0.6831**
	At	-1.9992*	0.3432			
	pH	6.0705**	2.0611			
	Tur	0.3099*	0.1372			
Bc	Cl	0.2038**	0.0483	-4.8028*	1.9976	0.4473**
Hemiptera Da	PO ₄	6.7949**	2.4331	1.8931	1.1033	0.2617*
Dr	NO ₃	9.1829**	2.0225	-1.5377	0.9815	0.4837**
Ps	BOD	-0.5481**	0.1477	4.2485*	2.0999	0.7355**
	COD	-0.1045**	0.0252			
	Hard	0.0560*	0.0261			
	TDS	-0.0263**	0.0092			
Rs	BOD	0.4963**	0.1274	3.6821*	1.7815	0.5961**
	TDS	-0.0263**	0.0087			
Coleoptera Hs	At	-1.6721**	0.4045	-0.5132	10.3860	0.6245*
	Hard	0.3615**	0.1012			
	Con	0.0623*	0.0218			
	Tur	0.4993*	0.2013			
Diptera Cs	DO	32.5915*	11.9149	90.7110	168.1547	0.7919**
	Wt	-8.8184*	3.5577			
Gastropoda Bb	Cl	8.3476**	2.8684	346.5472*	125.4041	0.4333**
	PO ₄	-298.3797*	114.5161			
Go	BOD	22.9291**	5.6212	-293.0807**	56.5159	0.7322**
	Hard	3.5495**	0.8802			
Dc	NO ₃	48.8821**	7.8359	-7.1649	3.8026	0.6388**

Table 25. Contd.

Dominant Macrofaunal Species	physico Chemical Parameters	Multiple regression values between Physicochemical and biological parameters				
		β_j	SE β_j	β_o	SE β_o	R ²
Tg	PO ₄	-17.1350*	6.7751	46.1322**	3.0723	0.2252*
Tt	TDS	0.1532*	0.0704	-10.5502	11.0277	0.4434**
	Tur	0.7857*	0.3501			
Brc	BOD	-4.3108**	1.1774	18.9821	15.3625	0.8098**
	PO ₄	31.0288**	8.0567			
	TDS	0.3857**	0.0810			
Gl	Cl	0.4288*	0.1688	87.0584**	15.3288	0.7320**
	PO ₄	-22.7207**	6.6876			
	Wt	-2.3400**	0.6691			
Bivalvia Pc	Hard	0.3553**	0.1209	-16.7305*	7.8438	0.2818**
Pisces Gg	TDS	-0.0349**	0.0093	7.9272**	1.5750	0.3902**

Note : β_j = Partial regression coefficient, β_o = Constant, SE = Standard error, R² = Coefficient of determination, * = Significant at 5% level of significance, ** = Significant at 1% level of significance. For full name of abbreviation vide list of abbreviation.

Table 26. Stepwise multiple regression analysis between physicochemical parameters and dominant macrofaunal species in terms of biomass (gm/m²) in RS.

Dominant Macrofaunal Species	Physico Chemical Parameters	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Oligochaeta Lh	PO ₄	0.0046**	0.0008	0.0009*	0.0004	0.5592**
Crustacea Md	At	-0.2683**	0.0317	10.4375**	0.9172	0.7644**
MI	TDS	-0.0038**	0.0011	1.8405**	0.2684	0.3501**
Odonata Pm	COD	0.1639*	0.0618	-0.7780	1.8097	0.2424
Bc	BOD	-0.0129**	0.0036	-0.0762**	0.0230	0.7696**
	Cl	0.0015**	0.0003			
	COD	0.0016*	0.3336			
	Tur	0.0029**	0.0005			
Hemiptera Da	Hard	-0.0227*	0.0103	3.0658*	1.0961	0.1806*
Dr	Amon	0.0597*	0.0230	-0.1778**	0.0349	0.8732**
	Hard	0.0008**	0.002			
	COD	-0.1045**	0.0252			
	NO ₃	0.1437**	0.0138			
	Tur	-0.0017**	0.0004			
Ps	COD	0.0001**	0.0001	-0.0008	0.0006	0.3575**
Rs	Wt	-0.0050	0.0013	0.1950	0.0362	0.4105**
Coleoptera Hs	FCO ₂	0.0085**	0.0029	0.0072	0.0042	0.6721**
	NO ₂	0.0799**	0.0172			
Gastropoda Bb	Amon	-120.6336**	24.8989	130.8215**	26.0746	0.7971**
	DO	-19.3169**	5.1955			
	NO ₃	163.2320**	26.8135			
Go	NO ₂	-9.5737**	3.3129	7.8299**	0.7362	0.6282**
	pH	-5.4883**	1.3122			
Dc	NO ₂	3.1534**	0.7632	0.1211	0.5674	0.6974**
	Con	-0.0039**	0.0009			
	Wt	0.0913**	0.0292			

Table 26. Contd.

Dominant Macrofaunal Species	physico Chemical Parameterers	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_o	SE β_o	R^2
Tg	Amon	-26.0914*	9.2991	36.8113	2.6718	0.7510**
	FCO ₂	4.7679*	2.1944			
	PO ₄	-11.3571*	5.1735			
Tt	NO ₂	-6.1297**	1.2604	7.4456**	0.9144	0.6758**
	TA	-0.0107**	0.0025			
Brc	Cl	-0.6456**	0.1811	98.8409**	21.0146	0.8675**
	DO	-14.3375**	3.5547			
	NO ₃	114.4675**	21.9330			
Gl	BOD	-0.1388*	0.0540	6.9356**	0.9781	0.8834**
	DO	-0.4060**	0.1105			
	FCO ₂	-1.3316**	0.2358			
	NO ₂	-2.7403**	0.7063			
Bivalvia Pc	Hard	0.0022**	0.0004	-0.0547	0.0638	0.5657**
	Wt	-0.0049*	0.0019			
Pisces Gg	At	0.0281**	0.0061	0.1476	0.1058	0.8755**
	NO ₃	-0.0928*	0.0434			
	PO ₄	-0.1326**	0.0252			
	TA	0.0003**	0.0001			
	Wt	-0.0315**	0.0053			

Note : β_j = Partial regression coefficient, β_o = Constant, SE = Standard error, R^2 = Coefficient of determination, * = Significant at 5% level of significance, ** = Significant at 1% level of significance. For full name of abbreviation vide list of abbreviation.

Table 27. Stepwise multiple regression analysis between physicochemical parameters and dominant macrofaunal species in terms of biomass (gm/m²) in SS.

Dominant Macrofaunal Species	Physico Chemical Parameters	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R ²
Oligochaeta Lh	FCO ₂	0.0010**	0.0003	-0.0002	0.0004	0.7215**
	PO ₄	0.0036**	0.0007			
Crustacea Md	At	-0.1656**	0.0363	6.3988**	1.0581	0.4862**
MI	Con	-0.0063*	0.0023	3.9700**	0.9410	0.2516*
Odonata Bc	Cl	0.0021**	0.0001	-0.0484*	0.0211	0.4261**
Hemiptera Da	PO ₄	0.8850*	0.3168	0.2460	0.1436	0.2619*
Dr	NO ₃	0.1437**	0.0309	-0.0243	0.0149	0.4955**
Ps	BOD	-0.0002**	0.0001	-0.0022**	0.0006	0.5985**
	COD	0.0001**	0.0001			
	NO ₂	-0.0055*	0.0025			
Rs	BOD	0.0206**	0.0052	0.1449*	0.0728	0.5977**
	TDS	-0.0015**	0.0003			
Coleoptera Hs	At	-0.0200**	0.0045	0.0080	0.1161	0.6537**
	Hard	0.0043**	0.0011			
	Con	0.0007**	0.0002			
	Tur	0.0060*	0.0022			
Diptera Cs	DO	-0.0156*	0.0058	0.0638	0.0814	0.8116**
	Wt	-0.0049**	0.0017			
Gastropoda Bb	Cl	1.8493**	0.6356	76.8559*	27.7897	0.4330**
	PO ₄	-66.0489*	25.3769			
Go	BOD	0.2773**	0.0661	-3.4499**	0.6645	0.7348**
	Hard	0.0418**	0.0103			
Dc	NO ₃	3.6478**	0.5877	0.5327	0.2851	0.6365**
Tg	PO ₄	-2.6035*	0.9926	6.8848**	0.4501	0.2382*
Tt	TDS	0.0111*	0.0051	-0.7476	0.8040	0.4616**
	Tur	0.0615*	0.0255			

Table 27. *Contd.*

Dominant Macrofaunal Species	physico Chemical Parameterers	Multiple regression values between physicochemical and biological parameters				
		β_j	SE β_j	β_0	SE β_0	R^2
Brc	PO ₄	44.4955**	7.8683	9.9734	8.8364	0.6753**
	Tur	1.2589**	0.4161			
Gl	PO ₄	-0.1629**	0.0309	0.1850**	0.0140	0.5585**
Bivalvia Pc	DO	0.1881**	0.0524	-1.6088**	0.4797	0.4780**
	FCO ₂	0.1758*	0.0840			
	Tur	0.0182**	0.0058			
Pisces Gg	TDS	-0.0019**	0.0005	0.4221**	0.0856	0.3808**

Note : β_j = Partial regression coefficient, β_0 = Constant, SE = Standard error, R^2 = Coefficient of determination, * = Significant at 5% level of significance, ** = Significant at 1% level of significance. For full name of abbreviation vide list of abbreviation.

These two categories of macrophytes jointly control 73% variation of the total macrofaunal abundance. The β_j values indicate that macrofaunal abundance increases linearly along with the increase of wet weight biomass of total macrophytes but if the amount of marginal macrophyte increases the abundance is likely to decrease sharply. So, the other categories of macrophytes *viz.*, floating, submerged and emergent macrophytes are expected to influence the macrofaunal abundance much more. On the other hand, total macrofaunal biomass is directly controlled by the wet weight biomass of submerged macrophytes and solely explains the 51% variation. Here the equation can be formed as follows :

$$\text{Total macrofaunal biomass} = 6.3945 + 0.0449 (\text{Wet Weight biomass of submerged macrophyte})$$

It may be noted that for every increase of 100gm wet weight biomass of submerged macrophytes, macrofaunal biomass (dry weight) increases about 4gm/m². Similar type of equation can be made for other faunal parameters like Total macrofauna.

F. Multiple regression analysis between macrophyte biomass and macrofaunal components in terms of abundance (no/m²) as well as biomass (gm/m²) in Subhas Sarovar

Result summarised in Table 29 shows the values of partial regression coefficients, constant values, their standard error and R² values for respective groups and total macrofauna and explains the condition of the lakes. As for example, the equation formation for coleopteran density, where constant value is negative is given below :

$$\text{Coleopteran density} = -1.6712 + 0.8408 (\text{Eichhornia dry weight biomass})$$

From the equation it is interesting to note that coleopteran existence (1/m²) is possible only when the dry weight biomass of *Eichhornia* reaches more than 3.18 gm/m², if the other variables remain constant.

G. Multiple regression analysis between macrophyte biomass and abundance of dominant macrofaunal species in Rabindra Sarovar

All the 20 regularly occurring species are subjected to stepwise multiple regression analysis to form the equation. Among them, the most dominant macrofaunal species *Bellamya bengalensis* (Bb) is found to be influenced by dry weight biomass of marginal macrophyte and *Vallisneria*. These two categories of macrophyte jointly explain 67% variation of the abundance of Bb. *Vallisneria* positively influences the Bb population while marginal macrophytes makes negative influence. Similar type of conclusion can be drawn for other independent variables as reflected in Table 30.

H. Multiple regression analysis between macrophyte biomass and abundance of dominant macrofaunal species in Subhas Sarovar

Here also the abundance of Bb shows the linear relationship with the dry weight biomass of submerged macrophytes. In SS, submerged macrophytes, during the period

Table 28. Stepwise multiple regression analysis between macrophytal biomass and macrofaunal components in terms of abundance (no/m²) as well as biomass (gm/m²) in RS.

Macrofaunal components	Macrophyte Category and Species	Multiple regression values between macrophyte biomass and macrofaunal components				
		β_j	SE β_j	β_0	SE β_0	R ²
	A. IN TERMS OF ABUNDANCE					
Total Macrofauna	T.Mac-w	0.2573*	0.0985	669.5960	490.6401	0.7313**
	Mm-w	-12.5896**	3.0226			
Oligochaeta	Sm-d	-0.1645**	0.0235	50.9219**	4.7312	0.6908**
Hirudinea	Val-d	0.0313**	0.0093	3-0.7482	0.6316	0.3395**
Crustacea	T.Mac-w	0.0096*	0.0041	19.2710	18.2559	0.1990*
Ephemeroptera	Cer-d	0.0425**	0.0106	04.4232**	1.5519	0.4651**
	T.Mac-w	-0.0019**	0.0006			
Odonata	Cer-d	-0.0773*	0.0284	31.2971**	4.8729	0.4068**
	Pi-d	-0.8814**	0.2760			
Coleoptera	Alt-d	-1.0022*	0.3552	1.3987**	0.3203	0.8552**
	Em-w	0.1134**	0.0368			
	Pi-d	0.0553*	0.0262			
Diptera	Mm-d	-2.0141*	0.7292	17.4243**	3.6743	0.2575*
Gastropoda	T.Mac-w	0.2551*	0.0936	530.5949	466.4780	0.7476**
	Mm-w	-12.4938**	2.8737			
Bivalvia	Em-d	-0.2162*	0.0929	7.1592**	1.6769	0.1973*
Pisces	Mm-d	-0.4562*	0.2157	5.2764	1.0869	0.1690*
	B. IN TERMS OF BIOMASS					
Total Macrofauna	Sm-w	0.0449**	0.0093	6.3945	33.6293	0.5121**
Oligochaeta	Sm-b	-0.0001**	0.0001	0.0072**	0.0005	0.6755**
Hirudinea	Val-d	0.0016**	0.0005	-0.0430	0.0322	0.3489**
Crustacea	Sm-d	0.0276**	0.0085	1.3843	1.7107	0.3252**

Table 28. *Contd.*

Macrofaunal components	Macrophyte Category and Species	Multiple regression values between macrophyte biomass and macrofaunal components				
		β_j	SE β_j	β_0	SE β_0	R^2
T. Insecta	Alt-d	0.1672**	0.0248	2.8456**	0.5716	0.7345**
	Ei-d	-0.0687**	0.0161			
	Mm-d	-0.2578**	0.0719			
	Val-d	0.0167**	0.0057			
Ephemeroptera	Mm-w	-0.0001*	0.0001	0.0050**	0.0009	0.2049*
Odomata	Cer-d	-0.0003*	0.0001	0.1462**	0.0215	0.4165**
	Pi-d	-0.0040**	0.0012			
Hemiptera	Alt-d	0.0918**	0.0142	2.2477*	0.5339	0.6802**
	Ei-d	-0.0541**	0.0147			
Coleoptera	Em-d	0.0081**	0.0015	0.2327*	0.0275	0.5634**
Diptera	Sm-w	0.0002**	0.0000	-0.4189	0.2234	0.4124*
Gastropoda	Sm-w	0.0433*	0.0090	3.1234**	32.4507	0.5118**
Bivalvia	Em-d	-0.0038*	0.0016	0.1234**	0.0283	0.2088*
Pisces	Pi-d	-0.0213**	0.0068	0.4711*	0.0658	0.3111**

Note : β_j = Partial regression coefficient; β_0 = Constant; SE = Standard error; R^2 = Coefficient of determination; * = Significant at 5% level of significance; ** = significant at 1% level of significance; For full name of abbreviation vide list abbreviation; w = Wet weight biomass; d = Dry weight biomass

Table 29. Stepwise multiple regression analysis between macrophytal biomass and macrofaunal components in terms of abundance (no/m²) as well as biomass (gm/m²) in SS.

Macrofaunal Components	Macrophyte Category and Species	Multiple regression values between macrophyte biomass and macrofaunal components				
		β_j	SE β_j	β_0	SE β_0	R ²
	A. IN TERMS OF ABUNDANCE					
Total Macrofauna	Lud-d	-19.3396**	5.0540	1462.12**	83.2652	0.3996**
Oligochaeta	Lud -d	1.3929**	0.3325	26.7119**	5.3679	0.4538**
Arachnida	Pi-d	2.4068**	0.3325	0.9302	0.6827	0.7043**
Total Insect	Fm-d	3.3815**	1.1915	7.9938	31.0817	0.2680**
Ephemeroptera	Mac-d	-0.0014**	0.0003	2.0830*	1.1754	0.5663**
	Sm-w	0.0018**	0.0082			
Odonata	Em-w	-0.0282**	0.0082	39.9497**	8.2374	0.3743**
	Fm-d	-0.7106*	0.733			
Hemiptera	Pi-d	2.5968**	0.7086	10.5648**	1.4551	0.3790**
Coleoptera	Ei-d	0.8408**	0.2771	-1.6712	6.6472	0.2949*
Diptera	Fm-d	2.5833*	1.2103	-20.6224	31.5709	0.1716*
Gastropoda	Lud-d	-18.9798**	5.4364	1237.3202**	89.5644	0.3565**
Bivalvia	Mac-d	0.0020*	0.0008	-1.9058	4.2346	0.1942*
	B. IN TERMS OF BIOMASS					
Total Macrofauna	Lud-d	-1.6237*	0.6375	263.9104**	10.5022	0.2277*
Oligochaeta	Fm-w	0.0001*	0.0001	0.0329	0.0105	0.3338*
	Sm-w	-0.0001**	0.0001			
Arachnida	Pi-d	0.0125**	0.0015	0.0055*	0.0031	0.7511**
Total Insect	Fm-d	0.0392**	0.0120	0.3724	0.3518	0.3522*
	Mm-d	0.0197*	0.0090			
Ephemeroptera	Mac-d	0.0001**	0.0001	0.0015	0.0008	0.5065**
	Sm-w	0.0001**	0.0001			

Table 29. *Contd.*

Macrofaunal components	Macrophyte Category and Species	Multiple regression values between macrophyte biomass and macrofaunal components				
		β_j	SE β_j	β_0	SE β_0	R^2
Odonata	Alt-d	-0.0014**	0.0004	0.1351**	0.0171	0.3032**
Hemiptera	Lud-d	0.0166**	0.0053	0.7748*	0.0881*	0.3051**
Coleoptera	Fm-w	0.0006**	0.0001	0.0034	0.0682	0.3732**
Diptera	Fm-w	0.0009*	0.0004	-0.0821	0.1791	0.1661*
Gastropoda	Lud-d	-1.6633*	0.6370	243.6563**	10.4952	0.2366*
Bivalvia	Em-d	-0.0033*	0.0014	0.2843**	0.0548	0.1966*

Note : β_j = Partial regression coefficient; β_0 = Constant; SE = Standard error; R^2 = Coefficient of determination; * = Significant at 5% level of significance; ** = significant at 1% level of significance; For full name of abbreviation vide list abbreviation; w = Wet weight biomass; d = Dry weight biomass

under study, have been specially dominated by *Vallisneria*. So, it can be concluded from the observation of both the lakes that Bb prefers submerged vegetation with wider surface area. Other 19 dominant species also form various equation in which the independent variables controlling such dependent variables ranges from one to three (Table 31).

I. Multiple regression analysis between macrophyte biomass and dominant macrofaunal species biomass in Rabindra Sarovar and Subhas sarovar

The results of RS and SS are summarised in the Tables 32 and 33. In Rabindra Sarovar regression equation forms for 19 out of the 20 regular species (Ml failed to form the equation) both in terms of abundance and biomass. But in SS, only 10 out of 20 dominant species have been successful to form the equation both in case abundance and biomass. These means, comparatively higher fluctuation of different species has occurred in SS than RS.

4.9.4. Comments

The nature of interactions and relationship between the abiotic and biotic factors and within the biotic factors of aquatic ecosystem is not simple. Hence the following discussion deals with the observations of one level in relation to other with reference to their influence on each other. As the work on macrophyte associated macrofauna and their interaction with abiotic and biotic factor is very meagre, it is not possible to compare the various results of the present investigation. Still, some observations are discussed to visualise the condition of these two waterbodies (RS and SS).

In the present study the abundance and biomass of total macrofauna have been found to be positively correlated to dissolve oxygen, nitrate, total dissolved solid as evidenced from Pearson's r-value whereas positively controlled by nitrate, ammonium, and total dissolved solid as shown by multiple regression analysis. So, it can be concluded that total macrofauna prefer the nutrient rich condition of water along with ample amount of dissolved oxygen. Correlations between organic enrichment and abundance of benthic species have also been reported by Howmiller and Scott (1977) and Mozley and Howmiller (1977). Increased input of organic materials resulted in increase of macrozoobenthic invertebrate population (Danell and Anderson, 1982) and it is likely to be related to enrichment of nutrient (Nalepa, 1987). Ghosh and Banerjee (1996), while studying the macrobenthic faunal diversity of pisciculture ponds of West Bengal, noted positive correlation between the total benthic organisms and nitrogen and phosphorus contents of water. In the present investigation linear relationship of Total macrofauna with DO suggests that macrofauna usually prefers the macrophytic zone. The higher DO level in macrophytic zone is also reported by Singh *et al.* (1994). Adholia *et al.* (1990) noted negative relationship of macrozoobenthos with pH and phosphate which is also in conformity with the present study. Apart from the physicochemical parameters, the total macrofaunal abundance and biomass have been positively influenced by macrophytal biomass specially the submerged macrophytes including *Ceratophyllum* and *Vallisneria*. The reference towards the submerged

Table 30. Stepwise multiple regression analysis between macrophytal biomass and abundance of dominant macrofaunal species (no/m²) in RS.

Dominant Macrofaunal species		Macrophyte Category and Species	Multiple regression values between dominant macrofaunal species and macrophyte biomass				
			β_j	SE β_j	β_0	SE β_0	R ²
Oligochaeta	Lh	Sm-d	-0.1093**	0.0145	32.9935**	2.9236	0.7210**
Crustacea	Md	Sm-w	0.0057*	0.0026	19.5828*	9.2704	0.1851*
Odonata	Pm	pi-d	-0.3272*	0.1191	10.5539**	1.1585	0.2554*
	Bc	Alt-d	-1.3486**	0.3435	5.6153**	1.5749	0.8593**
		Cer-d	-0.0176*	0.0073			
		Em-d	1.0674**	0.3494			
		Lud-d	4.5661**	1.1536			
		Mm-w	-0.3923**	0.1236			
Hemiptera	Da	Alt-d	0.5907**	0.0898	13.0765**	3.3818	0.6942**
		Ei-d	-0.3220**	0.0929			
	Dr	Val-d	0.0290*	0.0109	0.4851	0.7435	0.2411*
	Ps	Cer-d	-0.0183*	0.0068	7.7283**	1.1244	0.5392**
		Em-d	-0.1424**	0.0288			
	Rs	Em-d	-0.0331**	0.0094	1.6400**	0.1698	0.3601**
Coleoptera	Hs	Em-d	0.0757**	0.0078	1.8003**	0.1003	0.8113**
Diptera	Cs	Md-d	-1.7276**	0.5926	14.4755**	2.9864	0.2786**
Gastropoda	Bb	Mm-w	-1.4718**	0.4937	129.169**	41.7584	0.6736**
		Val-d	2.7838**	0.5395			
	Go	Cer-d	4.0697**	0.5100	179.9687	89.5383	0.8908**
		T.Mac-d	-1.2354*	0.5435			
		Pi-d	-7.0767*	2.9418			
	Dc	Pi-d	1.1658**	0.1192	3.7727**	1.1593	0.8130**
	Tg	Cer-d	0.9122**	0.1199	14.5733	17.0617	0.7247**

Table 30. *Contd.*

Dominant Macrofaunal species	Macrophyte Category and Species	Multiple regression values between dominant macrofaunal species and macrophyte biomass				
		β_j	SE β_j	β_0	SE β_0	R^2
Tt	Mm-w	-0.3275**	0.0482	43.6446**	2.2016	0.6774**
Brc	T.mac-w	0.0143**	0.0047	-28.7789	20.8117	0.2973**
Gl	Mm-w	-2.9083**	0.9719	138.3243	115.8517	0.7361**
	Sm-w	0.0624*	0.0266			
Bivalvia	Pc	Fm-w	-0.0055*	0.0025	4.0758*	1.7606
		Lud-d	-4.1854**	1.1313		
		Md-d	4.0553*	1.1825		
Pisces	Gg	Cer-d	0.0101**	0.0029	0.7193	0.5243**
		Pi-d	-0.0683*	0.0281		

Note : β_j = Partial regression coefficient; β_0 = Constant; SE = Standard error; R^2 = Coefficient of determination; * = Significant at 5% level of significance; ** = significant at 1% level of significance; For full name of abbreviation vide list abbreviation; w = Wet weight biomass; d = Dry weight biomass

Table 31. Stepwise multiple regression analysis between macrophyte biomass (gm/m²) and abundance of dominant macrofaunal species (no/m²) in SS.

Dominant Macrofaunal species	Macrophyte Category and Species	Multiple regression values between dominant macrofaunal species and macrophyte biomass				
		β_j	SE β_j	β_0	SE β_0	R ²
Oligochaeta Lh	Mm-d	0.9315**	0.1944	15.3682**	3.3504	0.5107**
Odonata Bc	Em-w	-0.0062*	0.0022	6.9515*	2.4611	0.5564**
	Fm-d	-0.2333*	0.0676			
	Mac-w	0.0007*	0.0003			
Hemiptera Da	Em-d	0.0596*	0.0154	0.7760	0.4812	0.8566**
	Mm-w	0.0083**	0.0027			
	Pi-d	1.0696**	0.2238			
Coleoptera Hs	Ei-d	0.4936**	0.1188	-1.3805	2.8507	0.439**
Diptera Cs	Fm-d	2.9470*	1.3587	-25.4468	35.4412	0.1762*
Gastropoda Bb	Sm-d	0.5707**	0.1386	291.6694**	79.4648	0.4352**
	Go	Mac-w	0.0266**	5.3342	34.6205	0.3998**
	Brc	Sm-w	-0.0062**	81.8323**	7.1619	0.4354**
Gl	Em-w	0.7124**	0.2270	43.2548**	2.7156	0.6925**
	Em-d	-8.6528**	2.6363			
Bivalvia Pc	Mac - w	0.0016*	0.0007	-1.4324	3.8730	0.1673*

Note : β_j = Partial regression coefficient; β_0 = Constant; SE = Standard error; R² = Coefficient of determination; * = Significant at 5% level of significance; ** = significant at 1% level of significance; For full name of abbreviation vide list abbreviation; w = Wet weight biomass; d = Dry weight biomass

Table 32. Stepwise multiple regression analysis between macrophytal biomass (gm/m²) and biomass of dominant macrofaunal species (no/m²) in RS.

Dominant Macrofaunal species		Macrophyte Category and Species	Multiple regression values between dominant macrofaunal species and macrophyte biomass				
			β_j	SE β_j	β_0	SE β_0	R ²
Oligochaeta	Lh	Sm-d	-0.0001**	0.0000	0.0070**	0.0005	0.7525**
Crustacea	Md	T.Mac-w	0.0004*	0.0002	0.0002	0.6897	0.1827*
Odonata	Pm	Pi-d	-0.0012*	0.0004	0.0393**	0.0046	0.2260*
	Bc	Alt-d	-0.0136**	0.0034	0.0540**	0.0156	0.8634**
		Cer-d	-0.0001*	0.0000			
		Em-d	0.0108**	0.0034			
		Lud-d	0.0453**	0.0114			
		Mm-w	-0.0038**	0.0012			
Hemiptera	Da	Alt-d	0.0766**	0.0117	1.6833**	0.4394	0.6946**
		Ei-d	-0.0413**	0.0121			
	Dr	Val-d	0.0005**	0.0001	0.0020	0.0104	0.3606**
	Ps	Alt-d	-0.0000**	0.0000	0.0025**	0.0003	0.5722**
		Cer-d	-0.0000**	0.0000			
	Rs	Em-d	-0.0010*	0.0004	0.0660**	0.0072	0.2393*
Coleoptera	Hs	Em-w	0.0000**	0.0000	0.0220**	0.0018	0.7660**
Diptera	Cs	Cer-d	0.0019**	0.0004	-0.2629**	0.0751	0.5017**
		Mm-d	0.0154*	0.0071			
Gastropoda	Bb	Mm-w	-0.3184**	0.1019	28.5078**	8.6231	0.6970**
		Val-d	0.6088**	0.1114			
	Go	Cer-d	0.0489**	0.0061	2.3944*	1.0755	0.8862**
		T.mac-d	-0.0161*	0.0065			
		Pi-d	-0.0781*	0.0353			

Table 32. Contd.

Dominant Macrofaunal species	Macrophyte Category and Species	Multiple regression values between dominant macrofaunal species and macrophyte biomass				
		β_j	SE β_j	β_0	SE β_0	R^2
Dc	Ei-d	0.0185*	0.0088	-0.1623	0.2664	0.8143**
	Em-w	0.0232**	0.0075			
	Em-d	-0.2158**	0.0729			
	Pi-d	0.0504**	0.0142			
Tg	Mm-w	-0.3275**	0.0282	43.6446**	2.2016	0.6774**
Tt	Cer-d	0.0058*	0.0027	2.5299**	0.4829	2.5299**
	Mm-w	-0.0208*	0.0049			
Brc	T.mac-w	0.0123**	0.0042	-24.0662	18.6513	0.2789**
Gl	T.mac-w	0.0002*	0.0001	0.5826	0.5655	0.7471**
	Mm-w	-0.0165**	0.0035			
Bivalvia	Fm-w	-0.0000*	0.0000	0.0586*	0.0253	0.5076*
	Lud-d	-0.5865**	0.0163			
	Mm-d	0.0569**	0.0170			
Pisces	Cer-d	0.0005**	0.0001	0.0384	0.0269	0.5209**
	Pi-d	-0.0037*	0.0015			

Note : β_j = Partial regression coefficient; β_0 = Constant; SE = Standard error; R^2 = Coefficient of determination; * = Significant at 5% level of significance; ** = significant at 1% level of significance; For full name of abbreviation vide list abbreviation; w = Wet weight biomass; d = Dry weight biomass

Table 33. Stepwise multiple regression analysis between macrophytal biomass (gm/m²) and biomass of dominant macrofaunal species (no/m²) in SS.

Dominant Macrofaunal species		Macrophyte Category and Species	Multiple regression values between dominant macrofaunal species and macrophyte biomass				
			β_j	SE β_j	β_o	SE β_o	R ²
Oligochaeta	Lh	Mm-d	0.0001**	0.0001	0.0015**	0.0004	0.3165**
Odonata	Bc	Em-w	-0.0001*	0.0001	0.0712*	0.0258	0.5460**
		Fm-d	-0.0024**	0.0007			
		T.Mac-w	-0.0001*	0.0001			
Hemiptera	Da	Em-d	0.0077**	0.0020	0.1009	0.0630	0.8551**
		Mm-w	0.0010**	0.0003			
		Pi-d	0.1391**	0.1391			
Coleoptera	Hs	Ei-d	0.0059**	0.0014	-0.0236	0.0326	0.4573**
Diptera	Cs	Fm-d	0.0015**	0.0006	-0.0132	0.0179	0.1790**
Gastropoda	Bb	Sm-d	0.1264**	0.0307	64.7227**	17.6062	0.4351**
	Go	T.Mac-w	0.0003**	0.0001	0.0920	0.4110	0.3941*8
	Brc	Sm-w	-0.0055**	0.0013	70.9159**	6.0931	0.4592**
	Gl	Fm-d	0.0025**	0.0008	0.0863*	0.0359	0.7399**
		T.Mac-d	-0.0004*	0.0001			
		Sm-w	0.0001**	0.0001			
Bivalvia	Pc	Em-d	-0.0029*	0.0013	0.2352**	0.0506	0.1824*

Note : β_j = Partial regression coefficient; β_0 = Constant; SE = Standard error; R² = Coefficient of determination; * = Significant at 5% level of significance; ** = significant at 1% level of significance; For full name of abbreviation vide list abbreviation; w = Wet weight biomass; d = Dry weight biomass

macrophytes was evidenced from the study of several workers (Krecker, 1939; Rosine, 1955; Harrod, 1964; Krull, 1970; Dvorak and Best, 1982; Pandey *et al.*, 1994). Sarkar (1989), while studying the macrobenthos of a fresh water pond in West Bengal reported positive influence of alkalinity and water temperature on oligochaetes. Annelids were reported to be positively dependent on available nitrogen and phosphorus (Sarkar, 1992). Singh and Sinha (1993) reported positive correlation of oligochaete population with both carbonate and bi-carbonate alkalinity. Direct positive relationship of oligochaete with air temperature and phosphate was observed by Adholia *et al.* (1990). In the present study, an increase in oligochaete density is found to be influenced by corresponding increase in At, Wt, FCO₂, TA, TDS, PO₄, Cl, NO₂ and Amon which is in accordance with the findings of the above cited authors. Moreover, a strong negative relationship is established with DO that was also reported by Adholia *et al.* (1990). Singh and Sinha (1993) explained that oligochaetes are capable of surviving in water with low DO as their blood is rich in haemoglobin. Direct relationship of oligochaete population with marginal and emergent macrophytes may be due to their preference towards the shady marginal zone with low level of DO i.e. the zone with lower infestation of submerged vegetation which immensely takes part in the lion share of oxygen production. Hirudineans are not regular in occurrence. During the course of field survey they are found to crawl on the leaf surface of *Vallisneria*. Association with *Vallisneria* has also been established from the statistical analysis. Furthermore, it has been noted that they prefer the biotope with higher level of oxygen and nutrient rich condition as evidenced from the result of Pearson's correlation coefficient (Tables 16 and 17) and multiple regression values (Table 28).

Like Hirudinea, Crustacea also showed preference towards DO and NO₃. The crustacean also showed affinity towards the macrophyte-infested area, especially towards the area with submerged macrophytes. This type of affinity also referred by Tonapi (1980). Malhotra *et al.* (1990) observed that crustaceans exhibited peak population during high oxygen content of water in Lake Mansor, Jammu. The spiders (Arachnida) primarily are epineustonic form and like to move on the surface area of floating vegetation. Their abundance is directly influenced by dry weight biomass of *Pistia* as evidence from the present investigation (Table 29).

Singh and Roy (1991) reported that odonates and ephemeroptans were positively and significantly correlated with submerged macrophytic biomass but their correlation with emergent macrophytic biomass was significantly negative. This is in corroboration with the present findings.

Hemiptera showed positive relationship with DO, NO₂ and Amon and preferred the zone occupied by emergent and marginal macrophytes. Singh and Roy (1991) noted positive relationship with submerged vegetation, but no such relationship is established during present investigation. However, during field study, *Diplonychus annulatus* was found to occur at sites associated with *Alternanthera* sp. The statistical results also relates to this view.

Like Hemiptera, Coleoptera also exhibit positive relationship with DO, NO₂, Amon. This group has expressed positive relationship with water temperature indicating summer

peak for coleopteran population. As macrophyte is the most important determining factor for insect population, the statistical relationships with the macrophytes have been given much importance. Direct relationship with floating macrophytes as observed during present investigation was also evidenced from the work of Rai and Sharma (1991). According to Tonapi (1980) some species of Coleoptera deposited their eggs in the roots of aquatic plants where larvae and pupae develop whereas some species deposited their eggs on the floating vegetation.

The population of Diptera has been reported to be positively correlated with air temperature (Adholia *et al.*, 1990). Rai and Dutta Munshi (1978) and Roy *et al.* (1980) have observed the dominance of chironomids in weed infested areas of shallow pond. According to them, these faunal elements get favourable ground for mining and rich periphyton available as food on the under surface of floating vegetation. Tonapi (1980) explained that females oviposit eggs on aquatic vegetation. In the present study, among physicochemical parameters Diptera showed positive correlation with DO and NO₃ but they showed preference towards the zone infested with floating and submerged macrophytes.

In general, the insects showed positive and direct relationship with DO and NO₃ and towards macrophytal zone rather than open water. Relationship of dissolved oxygen with insect population was also reported by Sarkar (1989). Although Bais *et al.* (1992) observed significant but negative relationship with insect population to NO₃ but the present study revealed positive and significant relationship. This may be due to the difference in physicochemical as well as biological condition of the habitat concerned. The preference towards macrophytal zone is a general view and supported by many workers.

Total hardness and pH explain most of the difference in gastropod distribution in the littoral zone of lakes (Okland, 1990) and these two parameters are known to have greater affinity for lakes with high organic matter (Mauthon, 1992). Sarkar (1989) found that molluscs were positively correlated to alkalinity, pH and DO of water. Adholia *et al.* (1990) reported positive relationship of DO with gastropod abundance. The present investigation corroborates with the abovementioned views. The gastropod occurrence shows positive correlation with DO, hardness, chloride and TDS. Singh and Roy (1991) reported strong positive relationship of gastropods with submerged vegetation. This view is very much in accordance with the present investigation. Although showed special preference towards the submerged one i.e. *Vallisneria*, *Ceratophyllum* etc., the gastropod, in general, preferred an area with multispecific vegetation.

Bivalves were not regular in occurrence during the study and whenever observed they were usually found among the macrophyted zone, which is also evidenced from the result of correlation coefficient. Bivalves also showed positive correlation with BOD, TA, Con and Hard during the present investigation. Prakash *et al.* (1994) reported highly positive correlation existed between weed fish density and macrophytal biomass, which finds support from the present investigation especially with submerged macrophytes.

Junk (1973) emphasised the water as prime factor for the distribution and abundance of macroinvertebrate fauna in shallow water areas, but during the present investigation it has been observed that macrofaunal abundance was more related to vegetative growth than physicochemical conditions of water. Similar observation was made by Voigts (1976), Rai and Sharma (1991), Singh and Roy (1991). Role of vegetation in aquatic ecosystem for harbouring macrobenthic fauna also suggested by Gupta (1976). These relationships can easily be modified by factors such as composition of phyto-periphyton, calcium deposition or environmental conditions (Dvorak and Best, 1982; Rooke, 1984; Kornijow, 1989a). It is interesting to note that among the different macrophyte species, *Ceratophyllum* supported/ showed positive correlation with maximum number of macrofaunal species (5 out of 20 species in case of macrofaunal abundance and 6 out of 20 species in case of biomass). This confirms the general tendency that the greater the fragmentation of macrophytal leaves, the greater the faunal density and usually the higher taxonomical diversity of the associated animal populations (Krecker, 1939; Rosine, 1955; Harrod, 1964; Krull, 1970; Dvorak and Best, 1982).

CONCLUDING REMARKS

Rabindra Sarovar (RS) and Subhas Sarovar (SS), both are considered as an integral part of Calcutta's urban ecology. Hence, proper management is essential for these two important urban lakes. Towards this goal, a comprehensive knowledge about flora, fauna, abiotic components and their interrelationship is of utmost importance for which the present study was undertaken. Eventually two years indepth study of limnological profiles and macrophyte associated macrofauna of these two urban lakes (RS and SS) revealed higher trophic status along with greater macrophytic density and diversity in RS than SS. It has been observed that the macrofaunal abundance in these two lake ecosystems was more related with macrophytal growth than physicochemical condition of water. Although certain macrofaunal species have shown some specific preference, still, in general, maximum number of macrofaunal species preferred the submerged macrophyte, *Ceratophyllum demersum* with dissected leaf surface area. The abiotic and biotic components of RS and SS, however, showed marked seasonal/monthly fluctuation. In overall, these two lakes are moderately polluted as revealed from the value of Shannon-Weiner index of diversity but with no obvious stress on aquatic ecosystem health, as these two lake ecosystems are stable with long food chain and ample aquatic biodiversity.

From the present study, however, it can be suggested that both the lakes (RS and SS) need to be protected from any further deterioration of their water quality. Mention may be made that the present investigation undoubtedly provide some baseline data on the water quality as well as macrophyte-macrofaunal associations and inter-relationships with abiotic factors which may be utilised for making management strategies of these two important urban freshwater lakes in Calcutta. So, proper management measures from the lake authority and considerable attention and care from the lake users and lake loving local people can help to enable these two urban lakes to flourish and provide infinite utilities as well as sustainable ecosystem services to urban humanity.

SUMMARY

1. The present study dealt with seasonal abundance and population fluctuation of macrophyte associated macrofauna along with physicochemical factors of two urban freshwater lakes of Calcutta, namely, Rabindra Sarovar (RS) and Subhas Sarovar (SS). Statistical interpretations are made to understand the community structure and functional interrelationships between macrophytes and macrofauna.
2. Besides temperature and meteorological data, 16 limnological parameters were tested following standard methods.
3. Quantitative fortnightly samplings were made by a box type sampler (20 X 20 X 40 cm³) at different depth of three selected stations of each lake, while qualitative samplings were made seasonally by means of hand picking, drag netting and by a box type sampler.
4. Five biological indices *viz.*, Shannon's index of diversity, Species richness index, Index of dominance, Evenness index and Index of similarity were calculated along with statistical analysis using computerised statistical package, SPSS version 6.0.
5. The meteorological data revealed that the climate of Calcutta is characterised by a distinct seasonality of rainfall, dry summer period and comparatively cooler winter season.
6. The physicochemical parameters showed distinct temporal or seasonal variation in both the lakes.
7. Comparatively higher DO content and lower FCO₂ content have been recorded in RS than SS. This may be due to higher macrophytal density and diversity in RS than SS. Both BOD and COD values of lake water are found to be lower during winter.
8. pH values have revealed alkaline nature of water in both the lakes. Total alkalinity was, however, higher in monsoon and lower in winter. The ionic strength of RS was greater than SS, as evidenced by the higher conductivity values of RS.
9. Maximum values of hardness and turbidity were recorded during summer. The water of both the lakes became more turbid during monsoon due to greater inflow of muddy rainwater from the surrounding catchment area.
10. There has been comparatively higher nutrient content in RS than SS, which signifies its eutrophication status/higher trophic level.
11. A total of 23 species of aquatic macrophytes belonging to 16 plant families and 20 plant genera were recorded of which RS shows higher macrophytic diversity (21 species) than SS (17 species).
12. Qualitative study of macrofauna associated with macrophytes revealed a total of 107 macrofaunal species represented by 54 families and 87 genera. RS and SS are found to be almost equally rich in species diversity, representing 94 and 91 species respectively.

13. Out of six selected macrophyte species, two from each of floating and submerged and one each from emergent and marginal categories; the submerged species *Ceratophyllum demersum* supports maximum number of macrofauna (53 species) due to its characteristic leaf dissection, a feature providing easy compartmentalised space as well as greater surface area for sheltering diverse animal communities.
14. Gastropods, crustaceans and insects are the most dominant groups in both the lakes in terms of abundance.
15. The mean density of Total macrofauna associated with macrophytes was higher in RS (1395.75/m²) than SS (1294.23/m²) probably due to greater macrophytal density and diversity. Gastropoda, Hemiptera and Arachnida had higher percentage in RS, while Crustacea, Diptera, Oligochaeta, Coleoptera, Odonata, Hirudinea, Bivalvia, Pisces and Ephemeroptera were more abundant in SS.
16. Among 107 species of 12 major groups, 20 species of 9 groups were found to be dominant/regularly occurring during the study period (Oligochaeta-1, Crustacea-2, Odonata-2, Hemiptera-4, Coleoptera-1, Diptera-1, Gastropoda-7, Bivalvia-1, Pisces-1).
17. Among the 20 dominant species; Md, Ml, Pm, Dr, Ps, Rs, Go, Tg, Tt and Gl showed their peak density during premonsoon period in both the lakes. Monsoon peak was shown by Lh, Bc and Da, while post monsoon peak by Cs and Bb. But the species like Hs, Dc, Pc and Gg failed to show any particular trend in both the lakes.
18. Community analysis by means of various indices reveals the presence of diversified resources with fairly uniform distribution of macrofaunal species, complex and long food web ecosystem. Station 3 of RS and Station 2 of SS showed highest percentage of similarity between the sites with higher macrophytal as well as macrofaunal diversity.
19. Result of ANOVA–two way analysis indicates that macrofauna associated with macrophytes differs significantly among the different species of macrophytes. Stational/spatial variations were not so prominent in both the lakes except in case of gastropod in RS and Hemiptera in SS.
20. Total macrofauna prefers the nutrient rich condition of water with ample amount of dissolved oxygen as revealed from the result of Pearson's correlation and multiple regression analysis.
21. Macrofaunal abundance and biomass have been positively influenced by macrophytal biomass especially of the submerged macrophytes.
22. Oligochaete density was found to be positively influenced by increase in At, Wt, FCO₂, TA, TDS, PO₄, Cl, Con, NO₂ and also by emergent as well as marginal macrophytes.
23. Hirudinea prefers biotope with high level of DO and nutrient rich condition. Crustacea also prefers the macrophytal zone with higher DO and NO₃.

24. Arachnids are directly influenced by the dry weight biomass of *Pistia*. Hemiptera and Coleoptera both shows positive relationship with DO, NO₂ and Amon but Hemiptera prefers the zone occupied by emergent and marginal macrophytes while Coleoptera shows it's preference towards floating macrophytes. Preference towards the DO and NO₃ is also shown by Diptera.
25. Gastropods, the most dominant group, express positive correlation with DO, hardness, Cl and TDS. They showed strong positive relationship with submerged vegetation but greater preference towards the area with diversified vegetation.

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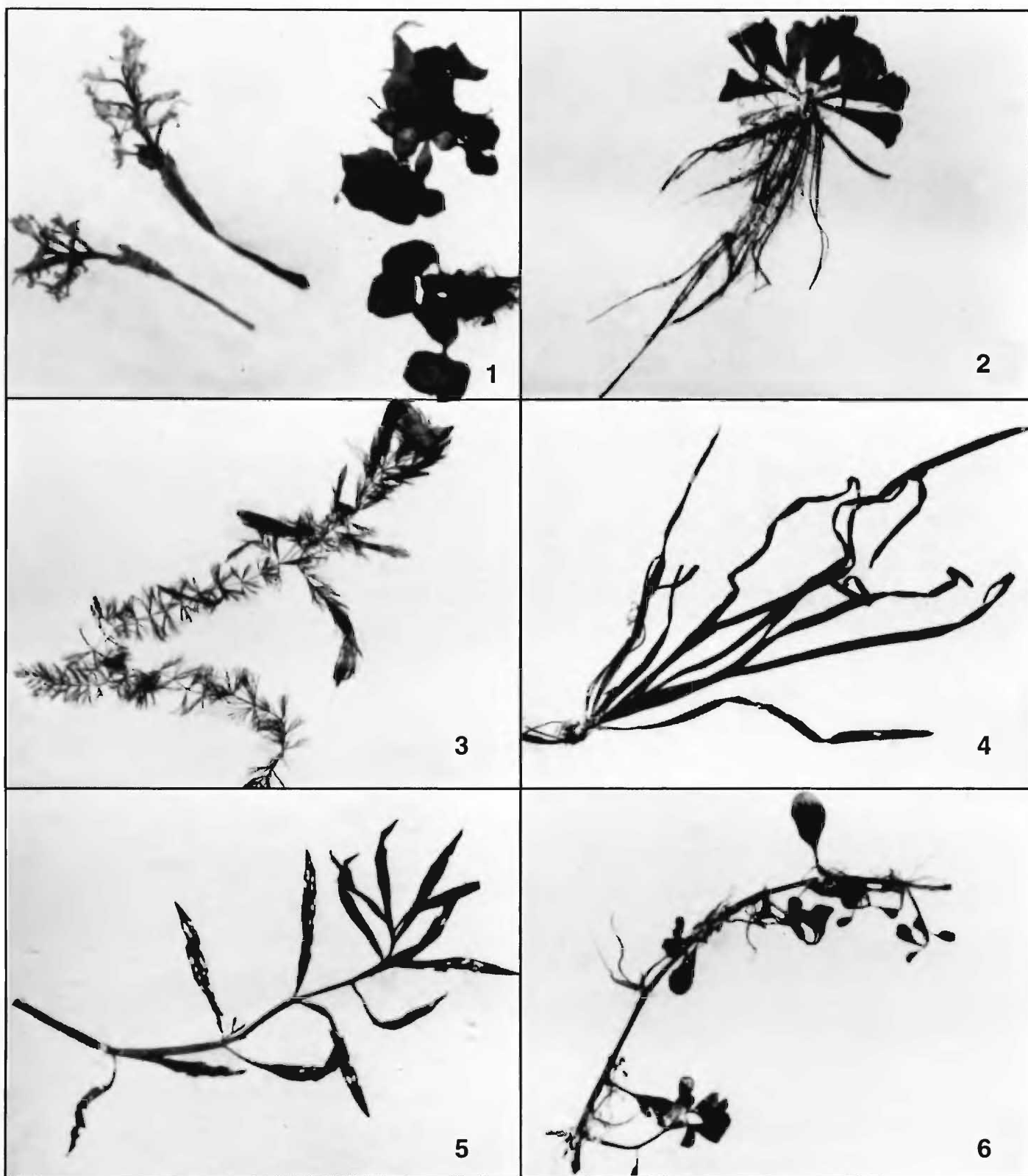


PLATE 1. (Fig. 1-6) Six species of macrophytes selected for study of macrophyte-macrofaunal assemblage.

- | | |
|------------------------|---|
| Floating macrophyte : | <i>Eichhornia crassipes</i> (Fig. 1) and <i>Pistia stratiotes</i> (Fig. 2) |
| Submerged macrophyte : | <i>Ceratophyllum demersum</i> (Fig. 3) and <i>Vallisneria spiralis</i> (Fig. 4) |
| Emergent macrophyte : | <i>Alternanthera philoxeroides</i> (Fig. 5) |
| Marginal macrophyte : | <i>Ludwigia adscedens</i> (Fig. 6) |

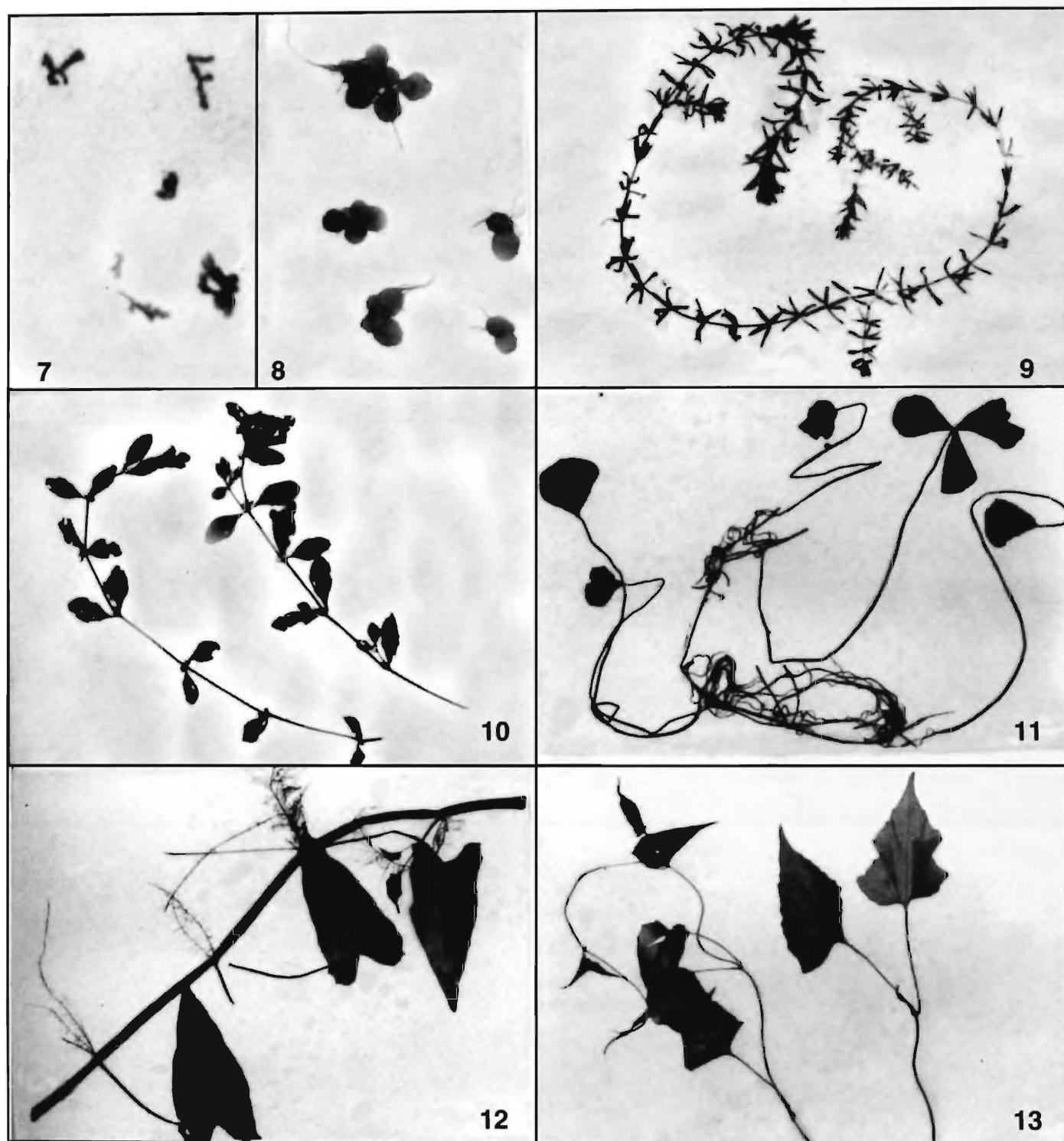


PLATE 2. (Fig. 7-13) Some other commonly occurring macrophytes of Rabindra Sarovar and Subhas Sarovar.

Fig. 7. *Azolla filiculoides*; Fig. 8. *Lemna minor*; Fig. 9. *Hydrilla verticillata*; Fig. 10. *Alternanthera sessilis*; Fig. 11. *Marsilea minuta*; Fig. 12. *Ipomea aquatica*; Fig. 13. *Mikania scandens*

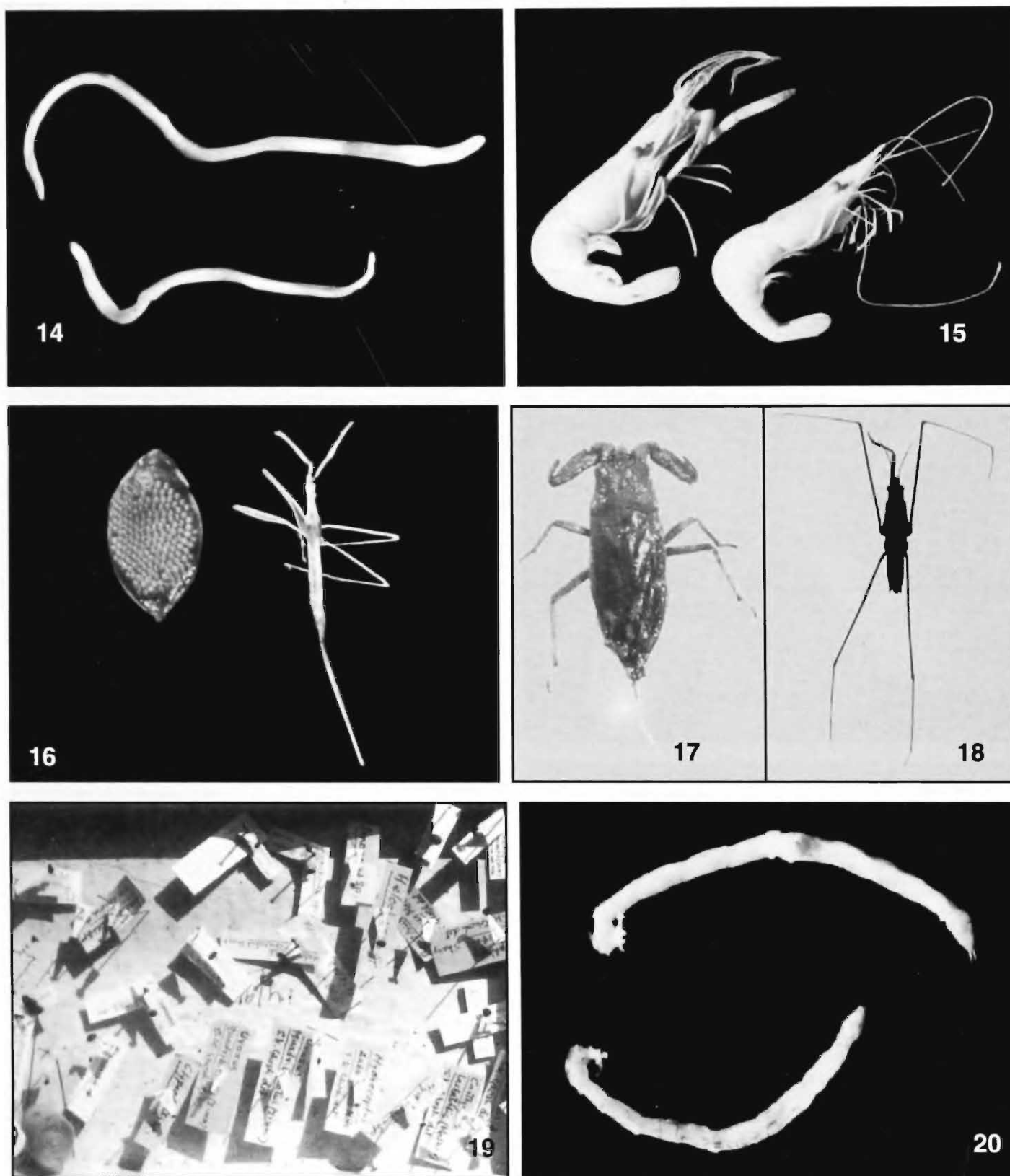


PLATE 3. (Fig. 14-20) Annelid and Arthropod species associated with macrophytes in Rabindra Sarovar and Subhas Sarovar.

Fig. 14. *Limnodrilus hoffmeisteri*; **Fig. 15.** *Macrobrachium dayanum* and *Macrobrachium lamarrei*; **Fig. 16.** *Diplonychus annulatus* and *Ranatra sordidula*; **Fig. 17.** *Laccotrephes griseus*; **Fig. 18.** *Gerris spinolae*; **Fig. 19.** Some Coleopteran representative; **Fig. 20.** *Chironomus* sp.

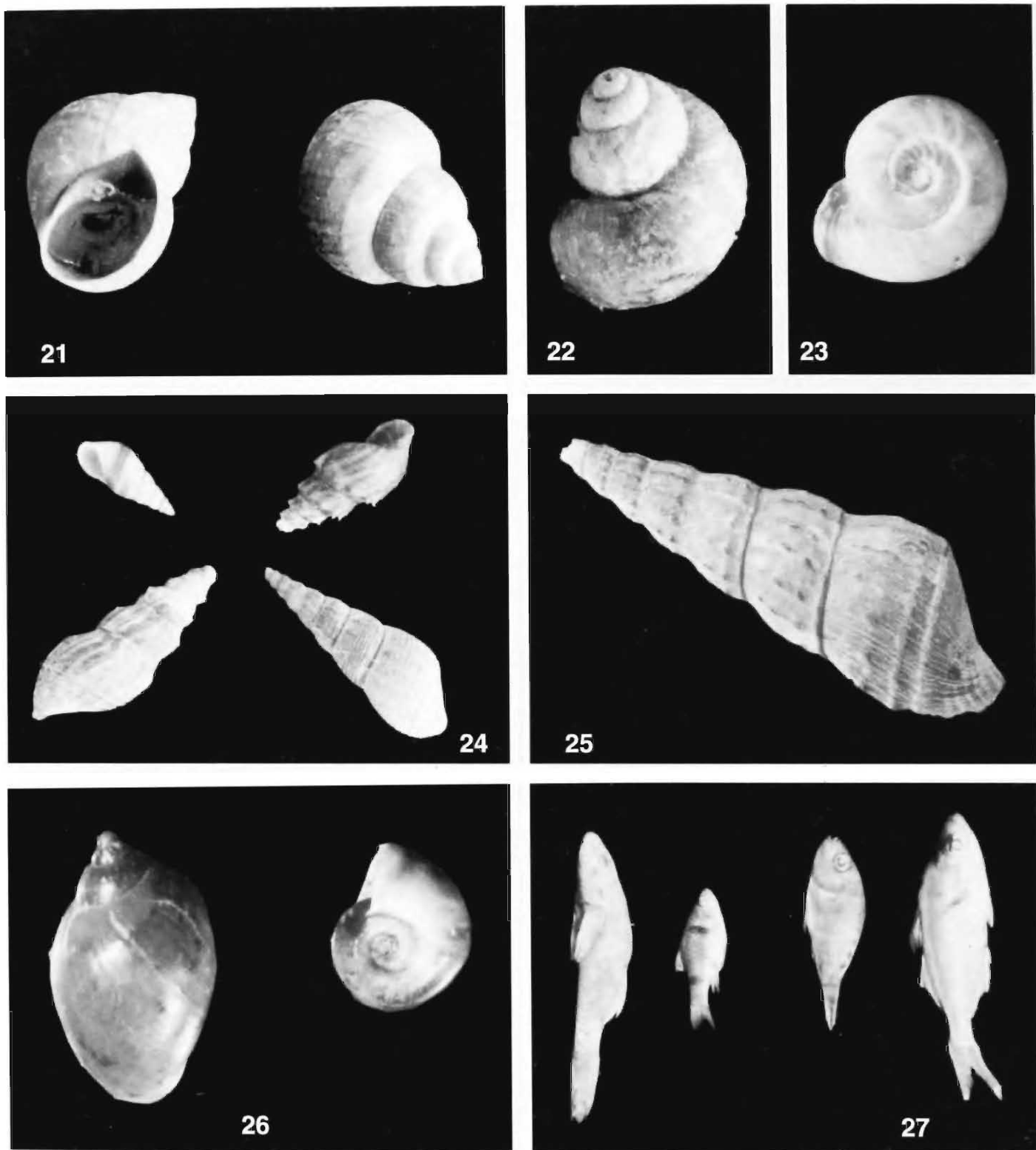


PLATE 4. (Fig. 21-27) Molluscs and fish species associated with macrophytes in Rabindra Sarovar and Subhas Sarovar.

Fig. 21. *Bellamya bengalensis*; Fig. 22. *Gabbia orcula*; Fig. 23. *Gyraulus labiatus*; Fig. 24. *Thiara* spp. [*Thiara lineata*, *Thiara scabra*, *Thiara tuberculata*, *Thiara granifera* (Top left to clockwise)]; Fig. 25. *Brotia costula*; Fig. 26. *Lymnaea luteola* and *Indoplanorbis exustus*; Fig. 27. Common weed fishes, *Glossogobius giuris*, *Puntius phutunio*, *Oreochromis nilotica* and *Ambassia nalu*.