ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 62 (3), 2010: 277-300

Relationship Among the Abundance of Waterbird Species Diversity, Macrophytes, Macroinvertebrates and Physico-chemical Characteristics in Santragachi Jheel, Howrah, W.B., India

Ashis Patra, Kalyan Brata Santra and Chanchal Kumar Manna***

Endocrinology Laboratory, Department of Zoology, University of Kalyani, Kalyani-41235, West Bengal, India;
E-mails:* kalyan_117@rediffmail and ** manna_kly@sify.com

Abstract: The present study has been designed with the aim of investigating the avifaunal diversity in Santragachi Jheel. Avifaunal population expresses distinct seasonal variation in this Jheel. Total 33 species belonging to 8 families and 23 genera were recorded which were categorized as resident, resident migratory and migratory birds. The population density of total avifauna was found to be maximum in winter. Family Anhingidae, Phalacrocoracidae and Ardeidae showed premonsoon maxima at all sites (S_1, S_2 and S_3) of Jheel. The abundance of family Rallidae and Anatidae was higher in winter whereas Jacanidae density expressed highest density in monsoon period. Higher values of Shannon-Wiener index of diversity and Margalef's species richness of avifauna were recorded in Santragachi Jheel. Highest value of avifaunal index of similarity was observed between S_1 and S_3 site of Santragachi Jheel. Bird's abundance is remarkably related with various physico-chemical parameters of water, macrophytes, macroinvertebrates and other physical factors of Jheel. Total avifaunal abundance was found to be positively influenced by dissolved oxygen (DO) and NO_3 in Jheel. Family Ardeidae has positive correlation with temperature of water (WT). Anatidae has expressed positive relationship with NO_3. Ardeidae has strong positive correlation with free floating type of macrophytes. Jacanidae family was positively influenced by total macrophytes (T-MACP) and free floating (FF) type of macrophytes. Total avifaunal population has been positively correlated with total macroinvertebrate abundance. Family Rallidae and Anatidae project positive correlation with crustacean population in the Jheel. Anatidae has positive correlation with Diptera and Gastropoda family. The population of the birds fluctuated seasonally between stations to station. A remarkable interrelationship was established between avifaunal density and trophic characteristics, especially phosphate content in Santragachi Jheel.

Keywords: Avifauna, Physico-chemical, Macrophytes, Macroinvertebrates, Shannon-wiener index

Introduction

As a conspicuous part of the biota of water bodies, water birds are indicators of their trophic state both in terms of species composition (quality) as well as occupancy and breeding (quantity). Birds may also influence the trophic state of a water body by importing nutrients (e.g. resident or migrating birds feeding on adjacent watersheds or the sea). One of the very important functions the wetlands perform is to provide suitable site for the breeding of the resident as well as a wintering ground for short and long distance migratory water birds. A wide variety of birds use wetland habitats for all or part of their life. They form one of the major components of the wetland ecosystems.

But now only little is known about the influence of birds on other species in ecological communities and on processes operating in ecosystems. Palmgren (1936) successfully related the trophic state of lakes (e.g. eutrophic, oligotrophic) to bird communities (species composition) and their abundance in some 60 water bodies in Aland, Finland. A water body's trophic status is a major factor influencing bird species abundance and richness (Murphy *et al.* 1984, Brown and Dinsmore 1986). Productive aquatic ecosystems are able to support a greater number of birds and more specialized species (Wright, 1983). Bird abundance and species richness is increased on eutrophic lakes because productive lakes have greater food resources (Hoyer and Canfield, 1994). Selection of wetlands by waterfowl is influenced by a complex of characteristics including water chemistry, aquatic vegetation, invertebrate fauna and physical features (Des Granges 1989, Heghund *et al.* 1994). Patterson (1976) performed the study on the role of environmental heterogeneity in the regulation of duck population. Swanson and Meyer (1977) and McIntyre (1988c) studied about the impact of water levels on feeding ecology of blue-winged teal.

Heglund *et al.* (1994) worked out the relationship between limnological characteristics of wetland and waterfowl population. North and Ryan (1989) explained about the characteristics of lakes and nest sites used by loons in Arctic Alaska. Consultants, limnologists and water-supply managers are interested in water birds because nutrients in their feces reduce water quality in lakes and reservoirs (Manny *et al.* 1994). Several works have been done on bird-nutrient relationship in different types of wetlands (Gere and Andrikovics 1992, Manny *et al.* 1994). Dobrowolski *et al.* (1976) and Gremillion and Malone (1986) indicated the birds as the cause of eutrophication in several Polish wetland. Vegetative habitat (macrophytes) has been reported by several workers as an important biotic factor controlling the selection of wetlands by waterfowl (Lillie and Evrard 1994, Hoyer and Canfield 1994). Several works have been done about the relation between macroinvertebrates and wetland related avifauna (McNicol and Wayland 1992, Lillie and Evrard 1994).

Although few works have been done by several scientists, very little is known about the ecology of wetland related birds, their diversity and relation with the trophic status of wetlands in India. Several works have been done on bird census in Indian wetlands (Ali 1933, 1963, Natarajan 1991, Nandi *et al.* 1993, Prashant *et al.* 1994, Kumar and Choudhury 1994, Barman *et al.* 1995, Srinivasulu *et al.* 1996, Prakash 2000). Prakash and Sharma (1995) explained the population density of wetland avifauna related to macrophytes, molluscs, insects and fishes. Sammaiah and Singh (2004) indicated the species diversity of water birds as a pollution indicator.

In West Bengal, Mukherjee (1975, 1976) studied on the food habits of waterbirds of Sundarbans. Ghosh (1990), Ghosh and Chattopadhyay (1990) listed some birds of wetlands of East Calcutta and Brace Bridge wetlands respectively. Zoological Survey of India and Nature Environment and Wildlife Society has done few works on water birds of West Bengal (NEWS 1998). Deuti *et al.* (1998) and Deuti (2000) observed Baikal Teal at Tilpara Barrage and Santragachi Jheel respectively. Ghosh and Chattopadhyay (1994) and NEWS (1998) made a generalized view about the avifauna of Santragachi Jheel. But all these works are done based on occasional and seasonal census of the bird. No work has been done in West Bengal on the relationship between wetland avifauna and trophic status of the wetland. No systematic and comprehensive report is available on the avifaunal diversity in Santragachi Jheel. So, to supplement the present knowledge in this subject the freshwater Jheel in the District of Howrah, W.B., has been chosen for conducting the surveys of avifauna and their relationship with wetland chracteristics including limnological, macrophytes and macroinvertebrate fauna during 2000-2002.

The objectives of the present work are (i) to study the avifaunal abundance in Santragachi, (ii) to determine the relationship between avifaunal abundance and physico-chemical characteristics of Jheel, (iii) to understand the interrelationship between avifauna and macrophytes, macroinvertebrates in Jheel, (iv) to find out the avifaunal population diversity in the selected Jheel, (v) to assess the pollutional impact on avifaunal diversity in the selected Jheel.

Materials and Methods

Study area

Santragachi Jheel (22° 58´N and 88° 27´E) is one of the most important urban wetland of the District Howrah, W.B., India. It is located on the southern side of Santragachi Railway station of South Eastern Railway, Govt. of India. This wetland was initially linked with the river Ganga, but now it is fed by rainwater. The Santragachi Jheel has received various sewage waters from the nearby localities of Howrah township. The total area of Santragachi Jheel is 10.87 ha. The shape of Santragachi Jheel is roughly rectangular. Its length is about 915 m and width is 305 m, perimeter is 2418 m and mean depth varies from 4-7 ft. Santragachi Jheel has been owned by South-Eastern Railways, but since August, 1992 the Wild-life wing of the Forest Department, Govt. of West Bengal has taken up management and developmental work of this wetland. Later on it would be included under a special wetland Circle of the Forest Department which is yet to be constituted. This Jheel is surrounded on all sides by human habitation including railway quarters, shops, railway yard, a number of industrial units, domestic and commercial cattle shed. Jheel has to receive domestic sewage water, waste materials, materials from unauthorized cow and buffalo sheds, fecal matters from the unwanted users of some parts of it, sewage waters from shops beside Jheel. There are about 11 sewage inlets surrounding it. People use some parts of Jheel as the dumping ground of their waste materials and garbage.

Sampling sites

To study the limnological changes, regular samplings of water were done fortnightly during February, 2000 – January, 2002 from three selected sites/stations of Jheel as follows:

Station 1(S_1): Located at the Western side of Jheel near the commercial cattle shed. Several sewage points are located on this side.

Station 2 (S_2): Located at the middle of Southern side and this station is devoid of sewage points.

Station 3 (S_3): Located at the Eastern side. Most of the major sewage points are located on this side.

Collection and preservation of water samples

Water samples were collected fortnightly in clear glass bottles from surface (max. depth 20 cm) and vegetated zone of three different sites/stations of Jheel. Water samples were collected in three replicates from surface, column and bottom of each station and mean values of all three 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-dioxide, total alkalinity and conductivity were measured in the field. Other parameters were mostly tested within 24 h of collection. Preservation of water samples was done at 4° C.

Analysis of water sample

A total of 17 limnological parameters of water viz., temperature, transparency, pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand, free carbon dioxide, total alkalinity, conductivity, $CaCO_3$ hardness, total suspended solid, total dissolved solid, chloride, ammonia, nitrite, nitrate and phosphate were determined. All the parameters were analyzed following the standard methods (Golterman 1969, Michael 1984; Trivedi and Goel 1984 and APHA, 1989) and by spectrophotometer SQ 118. Temperature of water (WT) was recorded by digital centigrade thermometer (-50 °C to +150° C). Transparency (Tr) was determined by standard Secchi disc. pH was determined by pH meter (model pH 320, Merck, Germany). Dissolved oxygen (DO) of water was estimated by Azide modification of Winkler's iodometric method (APHA, 1989). Biological oxygen demand (BOD) was estimated by measuring the amount of dissolved oxygen consumed by the sample in five days at 20 ^{0}C (APHA, 1989). Chemical oxygen demand (COD) was measured by refluxing the sample with potassium dichromate and sulphuric acid and then titrating the residual potassium dichromate against ammonium ferrous sulphate using feroin as an indicator (APHA, 1989). Free CO_2 (F

CO_2) was estimated by titrating 100 ml of sample solution by 0.0227(N) NaOH (Michael, 1984) using phenolphthalein as an indicator. Total alkalinity (TA) was measured by titrating 20 ml of water sample with 0.02(N) sulphuric acid using phenolphthalein and methyl orange as an indicator (APHA, 1989). Conductivity (con) was estimated by conductivity meter (Model LF320, Merck, Germany). $CaCO_3$ hardness (CaHa) was measured by EDTA titrimetric method (APHA, 1989), where the water sample was titrated with 0.01M EDTA titrant using Ediochrome black T dye and sodium chloride as a dry powder indicator. Total suspended solids (TSS) were obtained by filtering 250 ml of sample water and weighing the dried residue left over the filter paper. Total dissolved solids (TDS) were estimated as residue left after evaporation of filtered sample. Chloride (Cl) 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. Ammonia (Amn) was obtained by Micro-Kjeldahl distillation method. Nitrite (NO_2) was estimated colorimetrically by developing a colour with EDTA, sulphanilic acid, naphthylamine hydrochloride and sodium acetate (APHA, 1989). Nitrate (NO_3) was measured colorimetrically following phenol-disulphonic Acid method (APHA, 1989). Phosphate (PO_4) was determined colourimetrically by ammonium molybdate-stanous chloride method. Phosphate reacts with ammonium molybdate to form phosphomolybdic acid which on being reduced by stannous chloride produces a blue complex that was recorded spectrophotometrically.

Collection of macrophytes and macroinvertebrates

Collection of data on biotic component of Jheels was performed fortnightly along the littoral zone usually delimited by the rooted aquatic vegetation.

Qualitative sampling of macrophytes and macroinvertebrate fauna were made by means of hand picking, drag netting and a sampler measuring 20 x 20 x 40 cm^3 (Pal and Nandi, 1997) at different depth of three selected stations of each Jheel. For effective evaluation of the data, total 9 samples were taken from each station and in all 27 samples from each Jheel. For the isolation of macroinvertebrate fauna from weeds, the macrophytes enclosed in the sampler were soon washed thoroughly in water and filtered subsequently through a sieve of 0.5 mm mesh size (Havgaard 1973, Parsons and Mathews 1995). Macroinvertebrates retained in the sieve were brought to the laboratory and sorted in a large enamel tray in fresh condition. The sorted organisms were preserved in 70% alcohol. The macrophytes were manually collected, processed and herbaria were also prepared for identification.

Identification of macrophytes and macroinvertebrates

Identification of preserved macrophytes was done by consulting available literature sources (Biswas and Caldar 1936, APHA 1989, Ghosh 1994 Anonymous 1998). The macroinvertebrates associated with the macrophytes were identified with the help of the Experts of Zoological Survey of India, as well as using the available literature (Tonapai 1980, Srivastava 1993, Jayaram 1981, Subba Rao 1989, De and Sengupta 1993).

Biomass estimation of macrophytes

The biomass was determined as dry weight. The macrophytic samples were dried at 60° C for 48 h (Rai and Sharma 1991) and then weighed after cooling.

Determination of population density and percentage frequency

The number of individuals per unit area represents the population density. The number of macroinvertebrates associated with macrophytes was expressed as number of individuals per metre square using the formula put forward 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:

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

Bird census

Bird counts were carried out weekly from sampling sites S_1 to S_3 of the Santragachi Jheel. Bird census was carried out by fixed-width transect method (EMLEN 1971). The bird density (D) was calculated according to FRANZREB (1981) and CHAKRABORTY (1982) as

$$D = \frac{AZ}{2YX},$$

where A = Total area under study
Z = Number flushed
Y = Average flushing distance
X = Length of line

The number of birds visiting a study site in 15 min period was taken as one population count. The average value of 10 such counts represents the population of birds (BHAKTA and BANERJEE, 1995). All the observations were made using prismatic binoculars and telescope. Photographic documentation was done with a Nikon FM_2 camera with 400 mm. telephoto lens. Bird density was expressed as the number of birds per hectare of Jheel.

Identification of birds

Identification of birds was done initially with the help of experts of the Zoological Survey of India, Kolkata, W.B., INDIA. Subsequently the birds were identified using the reference collection and available literature (WHISTLER 1941, ALI and RIPLEY 1983b, WOODCOCK 1986, ALI 1996, WWF-India, 1998).

Analysis of species community

For the analysis of species community, five biological indices, viz., Shannon-Wiener index of diversity (SHANNON-WIENER 1949), Species richness (MARGALEF 1958), Index of dominance (SIMPSON 1949), Evenness index (PIELOU 1966) and Sorensen's index of similarity (SORENSON 1948) were employed for the.

Statistical analysis

Stepwise multiple regression

For the analysis of relationship between the controlling factors i.e., physico-chemical characteristics, macrophytes, macroinvertebrates and avifauna stepwise multiple regression method was applied. The analysis was worked out by SPSS programme, version 6.0.

Results

Physico-chemical characteristics

The result of different physico-chemical characteristics of water of the Santragachi Jheel are represented in Table 1 (PATRA *et al.* 2010).

Macrophytes

The aquatic macrophyte species recorded during this study period are listed in Table 2. Based on the habit of the macrophytes, they are broadly divided into six categories, viz., obligatory submerged or partially submerged plants with aerial shoot and inflorescence stalk, free floating, rooted floating leaved plants, rooted floating stem plants, emergent and marginal. These macrophytes are represented by 29 species belonging to 23

Macroinvertebrate fauna

Qualitative study reveals the presence of 3 major phyla represented by 69 species under 32 families.

Phylum Annelida includes Oligochaeta, represented by 2 species belonging to Tubificidae family and Hirudinea, represented by 2 species. 1 species belong to the family Glossophonidae and 1 species in Hirudidae (Table 3a).

Phylum Arthropoda includes Crustacea and is represented by 3 species. 2 species belong to the family Palaemonidae, and 1 species in the families Potamonidae. Arachnida is represented by 7 species under 4 families and Insecta by 41 species under 15 families (Table 3b).

Phylum Mollusca includes Gastropoda and is represented by 11 species under 6 families. Bivalvia is represented by 4 species under 2 families (Table 3a).

Avifauna of Santragachi Jheel

The avifaunal species recorded during the study period are listed in Table 4. The avifaunal diversity was represented by 33 species belonging to 8 families and 23 genera. Birds are divided into 3 categories, i.e., resident (R), resident migratory (RM) and migratory (M).

Table 1. Physico-chemical characteristics of water of antragachi Jheel (February, 2000 - January, 2002).

Physico-chemical characteristics	**Mean ± S.D.**
Water temperature (WT) (^{0}C)	27.58 ± 3.29
Transparency (Tr) (cm)	56.42 ± 8.58
pH	7.48 ± 0.49
Dissolved Oxygen (DO) (mg.l^{-1})	6.04 ± 1.59
Biological oxygen demand (BOD) (mg.l^{-1})	30.48 ± 6.05
Chemical oxygen demand (COD) (mg.l^{-1})	163.32 ± 31.48
Free CO_2 (F CO_2) (mg.l^{-1})	4.10 ± 1.12
Total Alkalinity (TA) (mg.l^{-1})	183.12 ± 31.18
Conductivity (Con) (µmos.cm^{-1})	898.53 ± 111.58
$CaCO_3$ hardness (CaHa) (mg.l^{-1})	223.72 ± 29.48
Total suspended solid (TSS) (mg.l^{-1})	199.52 ± 60.28
Total dissolved solid (TDS) (mg.l^{-1})	569.38 ± 75.39
Chloride (cl) (mg.l^{-1})	131.71 ± 31.98
Ammonia (Amn) (mg.l^{-1})	3.10 ± 0.28
Nitrite (NO_2) (mg.l^{-1})	0.17±0.10
Nitrate (NO_3) (mg.l^{-1})	1.01 ± 0.25
Phosphate (PO_4) (mg.l^{-1})	1.30 ± 0.31

Density of avifauna population (Ind/ha)

Monthly mean density of total avifauna ranged from 13.54 Ind/ha (October, 2000) to 687.86 Ind/ha (January, 2001). The population showed winter maxima at all three sites and mean abundance decreased from the year 2000-2001(124.84 Ind/ha) to the year 2001-2002(116.00 Ind/ha). The midwinter avifaunal abundance decreased remarkably at S_3 site from January, 2001 to January, 2002. Avifauna was represented by 8 families, which are summarized in Table 5a, 5b, 5c.

Anhingidae

Family Anhingidae is represented by *Anhinga rufa*. Maximum density of *Anhinga* rufa. (4.86 Ind/ha) was recorded at S_3 site during June, 2001.

Phalacrocoracidae

Family Phalacrocoracidae was represented by two species – *Phalacrocorax niger* and *Phalacrocorax fuscicollis*. It showed peak density in summer season at all sites. The population density was highest (7.12 Ind/ha) at S3 site during June, 2000. The density decreased in the winter season.

Ardeidae

The representatives of the family Ardeidae in the Santragachi Jheel are *Ardea alba*, *Bubulcus ibis*, *Egretta intermedia*, *Ardeola grayii*, *Nicticorax nycticorax*, *Ardea cinerea* and *Ardea purpurae*.

Ardea alba was very infrequent in Santragachi Jheel. Some *Ardea* sp. (0.30 Ind/ha at S_1 site, 0.26 Ind/ha at S_2 site and 0.45 Ind/ha at S_3 site) were observed in May-June, 2000. The population density of *Bubulcus ibis* varied from 0.41 Ind/ha at S_2 site during August, 2000 (Table 5b) to 7.90 Ind/ha at S_3 site during June, 2000. The population showed marked increase in pre-monsoon and declined considerably during monsoon period. *Egretta intermedia* showed maximum density at S_3 site (3.24 Ind/ha) during June, 2001. The population was lower at S_2 site than S_1 and S_3 sites. Peak density of *Ardeola grayii* was observed (7.90 Ind/ha) at S_3 site during June, 2001. The population density showed summer

Table 2 Occurrence of macrophytes in Santragachi Jheel.

Obligatory or partially submerged plants	**Free Floating**	**Rooted floating leaved plants**	**Rooted floating stem plants**	**Emergent**	**Marginal**
Family: Hydrocharitaceae	Family:Azollaceae	Family:Nymphaeaceae	Family:Amaranthaceae	Family:Acanthaceae	Family:Polygonaceae
Hydrilla verticillate (Linn.) Royle	*Azolla pinnate* Brown	*Nymphaea stellata* Burman	*Alternanthera sessilis* Linn.	*Hygrophila schulli* Hamilton	*Polygonum barbatum* Linn.
Family:Scrophulariaceae	Family:Pontederiaceae	*Nymphaea alba* Linn.	Family:Asteracea	Family:Araceae	*Polygonum hydropiper* Linn.
Limnophila indica Linn.	*Eichhornia crassipes* Marcius	Family:Pontederiaceae	*Enhydra fluctuans* Loureiro	*Colocasia esculenta* (L) Schott	Family: Onagraceae
Ottelia alismoides Linn.	Family:Lemnaceae	*Monochoria hastate* Linn.	Family:Convolvulaceae	Family:Cyperaceae	*Ludwigia adscendens* Linn.
	Lemna acquinoctialis Welwitsch		*Ipomoea aquatica* Forsskaal	*Cyperus pangorei* Roottbak	Family:Compositae
	Spirodella polyriza Linn.			*Juncelles inumdatus* Linn.	*Mikania scandens* Deny
	Family:Araceae			*Fimbristylis bisumbellata* Linn.	
	Pistia stratioites Linn.			Family:Convolvulaceae	
	Family:Salviniaceae			*Ipomoea fistulosa* Martinusex Choisy	
	Salvinia molesta Mitchell			Family:Amaranthaceae	
				Alternanthera philoxeroides Linn.	
				Family:Alismataceae	
				Sagittaria montevidensis Chamissoet Sc.	
				Family:Typhaceae	
				Typha domingensis Persoons	
				Family:Poaceae	
				Eragrostris sp. Linn.	

Table 3a. Qualitative occurrence of macroinvertebrate fauna (Annelida and Mollusca) associated with macrophytes in Santragachi Jheel.

Annelida	**Mollusca**
Oligochaeta	**Gastropoda**
Family: Tubificidae	Family: Viviparidae
Branchiura sowerbyi	*Bellamya bengalensis*
Limnodrilus hoffmeisteri	Family: Thiaridae
Hirudinea	*Brotia costula*
Family: Glossophonidae	*Thiara granifera*
Hemiclepsis marginata asiatica	Family: Bithyniidae
Family: Hirudidae	*Digoniostoma cemeopoma*
Hirudinaria manillensis	Gabbia orcula
	Family: Pilidae
	Pila globosa
	Family: Lymnaeidae
	Lymnaea luteola
	Lymnaea accuminata
	Family: Planorbidae
	Gyraulus convexiusculus
	Gyraulus labiatus
	Indoplanorbis exustus
	Family: Unionidae
	Lamellidens corrianus
	Lamellidens marginalis
	Family: Pisidiidae
	Pisidium clarkeanum

Table 3b. Qualitative occurrence of macroinvertebrate fauna (Arthropoda) associated with macrophytes in Santragachi Jheel.

Arthropoda		
Crustacea	**Arachnida**	**Insecta**
Order: Decapoda	Order: Araneae	Order: Ephemeroptera
Family: Palaemonidae	Family:Lycosidae	Family: Baetidae
Macrobrachium dayanum	*Evippa shivajii*	*Cloeon* sp.
Macrobrachium lamarrei	*Paradosa annandalei*	Order: Odonata
Family: Potamonidae	*Paradosa birmanica*	Family: Libellulidae
Sartoriana spinigera	*Paradosa pusiota*	*Brachythemis* sp.
	Family: Araneidae	Family:Coenagrionidae
	Larinia sp.	*Agrioenemis pygmaea*
	Family: Salticidae	*Ceriagrion coromandelianum*
	Myrmarachni sp.	*Ischnura senegalensis*
	Family: Theridae	*Ischnura aurora*
	Theridion sp.	*Pseudagrion* sp.
		Order: Hemiptera
		Family: Gerridae
		Gerris adeloidis
		Gerris spinolae
		Limnogonus sp.(2 species)
		Micronecta sp.
		Family: Hydrometridae
		Hydrometra sp. (2 species)
		Family: Nepidae
		Ranatra elongata

Table 3b. Continued.

Arthropoda		
Crustacea	**Arachnida**	**Insecta**
		Ranatra filiformis
		Ranatra sordidula
		Laccotrephes grisesus
		Family: Belostomidae
		Diplonychus annulatum
		Diplonychus sp.
		Family: Pleidae
		Plea sp.
		Family: Notonectidae
		Anisops breddini
		Order:Coleoptera
		Family: Chrysomelidae
		Dicladispa armigera
		Cassida sp.
		Family: Dytiscidae
		Hydrocoptus subvittulus
		Hydaticus fabricii
		Hydrovatus sp.
		Canthydrus laetabilis
		Canthydrus luctuosus
		Clypeodytes sp.
		Laccophilus sp.(2 species)
		Family:Hydrophilidae
		Amphiops pedestris
		Berosus indicus
		Helochares anchoralis
		Sternolophus rufipes
		Order: Diptera
		Family: Chironomidae
		Chironomus sp.(2 species)
		Family: Culicidae
		Anopheles sp.
		Culex sp.
		Family: Stratiomyidae
		Odontomyia dorsoangulata

maxima. Lowest population density was observed (0.53 Ind/ha) at S_2 site during December, 2000. *Nycticorax nycticorax* did not show any definite seasonal pattern. It was observed in summer month with maximum abundance in June, 2001 at S_3 site (0.48 Ind/ha). *Ardea cinerea* was very infrequent in occurrence with maximum abundance at site S_3 in January, 2001 (0.62 Ind/ha). The peak abundance of *Ardea purpurea* was observed in winter season. The maximum density was observed at S_3 site in February, 2001 (1.80 Ind/ha).

Rallidae

The mean density of the family Rallidae varied from 2.73 Ind/ha (April, 2000) to 12.80 Ind/ha (January, 2001). Peak density was observed in winter season. The population density is higher at S_3 site than S_1 and S_2 sites. The population density of *Rallus striatus* showed winter maxima. Maximum density was observed during January, 2002 at S_3 site (5.28 Ind/ha). *Porphyrio porphyrio* and *Gallinula chloropus* were observed only during winter season. Maximum density of *Porphyrio porphyrio* (4.02 Ind/ha) and *Gallinula chloropus* (9.20 Ind/ha) was observed at S_3 site during January, 2001. The abundance of *Fulica atra* was maximum at S_1 site during February, 2000 (6.90 Ind/ha). *Amaurornis phoenicurus* showed remarkable seasonal fluctuation in terms of abundance increasing during monsoon and postmonsoon with

Table 4. Avifauna of Santragachi Jheel recorded during the period February, 2000 – January, 2002 (R: Resident Bird, RM: Resident Migratory, M: Migratory).

Avifauna			
Family	**Common name**	**Scientific name**	**Status**
Anhingidae	Darter	*Anhinga rufa*	RM*
Phalacrocoracidae	Little Cormorant	*Phalacrocorax niger*	RM
	Indian Shag	*Phalacrocorax fuscicollis*	RM
Ardeidae	Great Egret	*Ardea alba*	RM
	Cattle Egret	*Bubulcus ibis*	R
	Median Egret	*Egretta intermedia*	RM
	Pond Heron	*Ardeola grayii*	R
	Night Heron	*Nycticorax nycticorax*	R
	Grey Heron	*Ardea cinerea*	RM
	Purple Heron	*Ardea purpurae*	RM
Rallidae	Banded Rail	*Rallus striatus*	RM
	Purple Moorhen	*Porphyrio porphyrio*	RM
	Indian Moorhen	*Gallinula chloropus*	RM
	Coot	*Fulica atra*	RM
	White Breasted Waterhen	*Amaurornis phoenicurus*	R
Jacanidae	Bronze Winged Jacana	*Metopidius indicus*	R
	Pheasant Tailed Jacana	*Hydrophasianus chirurgus*	R
Alcedinidae	Common Kingfisher	*Alcedo atthis*	R
	White Breasted Kingfisher	*Halcyon smyrnensis*	R
	Pied kingfisher	*Ceryle rudis*	R
Anatidae	Lesser Whistling Teal	*Dendrocygna javanica*	M
	Pintail	*Anas acuta*	M
	Common Teal	*Anas crecca*	M
	Gadwall	*Anas strepera*	M
	Shoveler	*Anas clypeata*	M
	Garganey	*Anas querquedula*	M
	Mallard	*Anas platyrhynchos*	M
	Cotton Teal	*Nettapus coromandelianus*	M
	Baikal Teal	*Anas formosa*	M
	Nakta	*Sarkidiornis melanotos*	M
Scolopacidae	Common Snipe	*Gallinago gallinago*	M
	Marsh Sandpiper	*Tringa stagnatilis*	RM
	Wood Sandpiper	*Tringa glareola*	M

the maximum density at S_3 site during August, 2000 (8.38 Ind/ha).

Jacanidae

Family Jacanidae was represented by two species – *Metopidius indicus* and *Hydrophasianus chirurgus*. Peak density of family Jacanidae was recorded in monsoon and post-monsoon season and it was higher at S_3 site than S_1 and S_2 sites. The population density of *Metopidius indicus* was significantly higher (8.42 Ind/ha) at S_3 site during September, 2001. *Hydrophasianus chirurgus* showed maximum density at S_3 site (3.00 Ind/ha) during September, 2000.

Alcedinidae

Family Alcedinidae was represented by the species *Alcedo atthis*, mean abundance was maximum during May, 2000 (0.71 Ind/ha), *Halcyon smyrnensis* showed maximum density at S_3 site (0.75 Ind/ha) during March, 2001 and *Ceryle rudis* did not show

Table 5a. Seasonal mean abundance (Ind/hectare) of dominant avifaunal species at S1 site Santragachi Jheel.

Year	Month	Dominant avifauna species																																
		*Aru	Pfu	Pni	Aal	Bib	Ein	Agr	Nny	Aci	Apu	Rst	Ppo	Gch	Fat	Aph	Min	Hch	Aat	Hsm	Cru	Dja ◙	Aac	Acr	Ast	Acl	Aqu	Apl	Nco	Afo	Sme	Gga	Tst	Tgl
2000 - 2001	Feb	1.99	0.00	1.56	0	2.82	0	2.54	0	0	0.07	2.24	0.51	4.88	6.90	1.58	1.79	0.21	0.45	0.59	0.45	351.12	64.08	1.68	6.93	8.64	10.08	2.54	9.60	0	0	1.58	0.72	0.26
	Mar	1.80	0.00	3.18	0	2.76	0	3.66	0	0	0	0.42	0	2.62	0.42	2.10	1.74	0	0.53	0.36	0	185.85	10.50	0	0.30	3.12	1.44	0.24	3.30	0	0	0.18	0.24	0
	Apr	2.24	0.36	2.22	0	3.05	0	2.58	0	0	0	0	0	0.90	0.30	3.12	2.52	0	0.62	0.44	0	3.66	0	0	2.07	0	0	0	0	0	0	0.42	1.02	0
	May	3.52	0.36	4.47	0.27	4.92	0.30	4.92	0	0.17	0	0	0	0	0	3.68	4.01	0	0.77	0.51	0	0	0	0	11.97	0	0	0	0	0	0	0.41	0.27	0
	June	3.44	0.24	4.96	0.30	5.29	0.57	5.36	0	0.32	0	0	0	0	0	4.39	1.81	0	0.42	0.55	0.29	0	0	0	0	0	0	0	0	0	0	0.47	0	0
	July	1.68	0.00	2.73	0	2.33	0	3.96	0	0	0	0	0	0	0	3.40	4.59	0	0.23	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	0.78	0.00	1.13	0	1.44	0	3.52	0	0	0	0	0	0	0	5.57	3.92	0	0.26	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	1.44	0.00	1.37	0	1.92	0	2.68	0	0	0	0	0	0	0	3.09	4.73	0.33	0.30	0.26	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0.56	0.00	0.89	0	2.47	0	2.46	0	0	0	0	0	0	0	5.98	3.72	0	0.29	0.28	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	1.02	0.27	1.13	0	2.26	0	1.68	0	0	0	0	0	0.48	0	4.74	1.77	0	0.31	0.30	0.19	24.80	1.01	0.56	2.07	0.48	0.47	0	0	0	0	0	0.27	0
	Dec	1.07	0.62	1.29	0	1.56	0	1.73	0	0	0	0.98	0.41	2.97	0.68	3.81	1.74	0.47	0.36	0.30	0.25	471.81	29.84	0.79	11.97	8.48	4.46	2.37	0	0	0	2.46	0.36	0
	Jan	1.09	0.53	1.09	0	1.73	0.27	1.94	0	0.47	0.27	3.18	1.92	5.18	0.84	0.95	1.02	0.77	0.37	0.43	0.28	829.13	66.72	8.07	21.86	17.48	21.47	2.10	4.49	0.26	0.32	2.76	0.35	0.24
2001 - 2002	Feb	1.25	0.92	1.47	0	1.92	0	1.68	0	0	0.76	1.47	1.38	2.46	1.22	1.92	1.95	0.35	0.59	0.62	0.27	474.80	13.76	0	8.09	8.01	8.96	0.42	2.88	0	0	0.47	0.30	0.22
	Mar	1.91	0	3.00	0	3.08	0.32	3.84	0	0	0	1.07	0	1.20	0.32	3.67	2.52	0.32	0.62	0.71	0.32	211.92	1.20	0	1.92	1.23	1.38	0	1.35	0	0	0	0	0
	Apr	2.87	0	2.96	0	3.68	0.81	3.81	0.21	0	0	0	0	0	0	3.94	1.56	0	0.50	0.44	0.31	2.18	0	0	0	0	0	0	0	0	0	0	0.32	0
	May	3.57	0	3.72	0	3.84	0.92	4.32	0.27	0	0	0	0	0	0	2.98	1.80	0	0.45	0.53	0.38	0	0	0	0	0	0	0	0	0	0	0	0.80	0
	June	4.56	0.30	4.95	0	6.56	1.56	5.09	0.23	0	0	0	0	0	0	3.60	5.21	0	0.62	0.56	0.50	0	0	0	0	0	0	0	0	0	0	0	1.26	0
	July	4.22	0	4.00	0	4.60	0.38	3.32	0	0	0	0	0	0	0	5.37	4.68	0	0.35	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0.27	0
	Aug	1.51	0	1.02	0	4.72	0.24	4.56	0	0	0	0	0	0	0	6.02	6.38	0.87	0.26	0.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	0.85	0	0.95	0	3.15	0	3.18	0	0	0	0	0	0	0	5.97	7.56	1.17	0.27	0.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0.97	0	1.44	0	2.56	0.47	2.45	0	0	0	0	0	0	0	4.47	4.86	0.36	0.47	0.38	0.26	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	1.83	0	1.68	0	3.70	0	2.69	0	0	0	1.08	0	0.27	0.57	1.82	2.76	0.33	0.38	0.41	0	27.50	1.08	0	0	0	0	0	0	0	0	0	0	0
	Dec	1.98	0	2.22	0	3.39	0	2.43	0	0	0	2.27	0.38	1.02	3.72	1.98	3.06	0.60	0.30	0.44	0	413.36	25.52	0	6.42	3.72	4.94	0	0.45	0	0	0.45	0	0.29
	Jan	2.10	0	2.09	0	2.67	0.35	2.55	0	0	0	1.82	1.94	3.72	0.62	2.10	2.85	0.45	0.38	0.42	0.24	696.08	63.63	0	15.32	11.97	21.21	0	2.91	0	0	1.92	0	0.47

*Aac: *Anas acuta,* Aal: *Ardea alba,* Aat: *Alcedo atthis,* Aci: *Ardea cinerea,* Acl: *Anas clypeata*
Acr: *Anas crecca,* Afo: *Anas Formosa,* Agr: *Ardeola grayii*, ALC: Alcedinidae, ANH: Anhingidae
ANT: Antidae, Aph: *Amaurornis phoenicurus,* Apl: *Anas platyrhynchos,* Apu : *Ardea purpurae*
Aqu: *Anas querquedula,* ARD: Ardeidae, Aru : *Anhinga rufa,* Ast : *Anas strepera*
Bib: *Bubulcus ibis,* Cru: *Ceryle rudis,*
Dja: *Dendrocygna javanica*, Ein: *Egretta intermedia,* Fat: *Fulica atra,* Gch: *Gallinula chloropus*
Gga: *Gallinago gallinago,* Hch: *Hydrophasianus chirurgus,* Hsm : *Halcyon smyrnensis*
JAC: Jacanidae, Min: *Metopidius indicus,* Nco: *Nettapus coromandelianus,* Nny: *Nycticorax nycticorax*
Pfu: *Phalacrocorax fuscicollis,* PHA : Phalacrocoracidae, Pni : *Phalacrocorax niger,* Ppo : *Porphyrio porphyrio*
RAL: Rallidae, Rst: *Rallus striatus,* SCO : Scolopacidae, Sme: *Sarkidiornis melanotos*
T-AV: Total Avifauna, Tgl: *Tringa glareola,* Tst: *Tringa stagnatilis*

Table 5b. Seasonal mean abundance (Ind/hectare) of dominant avifaunal species at S2 site Santragachi Jheel.

Year	Month	Dominant avifauna species																																
		Aru	Pfu	Pni	Aal	Bib	Ein	Agr	Nny	Aci	Apu	Rst	Ppo	Gch	Fat	Aph	Min	Hch	Aat	Hsm	Cru	Dja ◙	Aac	Acr	Ast	Acl	Aqu	Apl	Nco	Afo	Sme	Gga	Tst	Tgl
2000 - 2001	Feb	0.83	0	0.99	0	0.93	0	1.31	0	0	0	0.71	0.23	1.20	2.84	0.72	0.42	0.15	0.42	0.24	0.40	59.28	12.71	0.75	1.38	0.92	1.28	0.71	2.02	0	0	0	0.23	0
	Mar	0.90	0	1.50	0	0.78	0	1.62	0	0	0	0	0	0.39	0.30	0.80	0.66	0	0.44	0.28	0	29.88	1.80	0	0	0.42	0	0	0.38	0	0	0	0	0
	Apr	1.44	0.23	1.68	0	1.59	0	2.16	0	0	0	0	0	0.29	0	1.41	1.20	0	0.47	0.42	0	1.48	0	0	0	0	0	0	0	0	0	0	0.32	0
	May	1.48	0	1.44	0.26	1.92	0.27	2.42	0	0	0	0	0	0	0	1.07	0.89	0	0.61	0.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	June	1.53	0	2.48	0	3.09	0.35	3.12	0	0	0	0	0	0	0	1.38	1.78	0	0.38	0.30	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0
	July	0.90	0	1.52	0	1.52	0	1.85	0	0	0	0	0	0	0	1.48	1.48	0	0.19	0.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	0.27	0	0.62	0	0.41	0	1.81	0	0	0	0	0	0	0	0.38	0.47	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	0.48	0	0.30	0	0.65	0	1.53	0	0	0	0	0	0	0	1.16	0.62	0	0.25	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0.29	0	0.42	0	1.77	0	1.61	0	0	0	0	0	0	0	1.58	0.51	0	0.24	0.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0.47	0	0.39	0	1.92	0	0.59	0	0	0	0	0	0.23	0	1.47	0.60	0	0.26	0.19	0	4.2	0.63	0	0.38	0.23	0.28	0	0	0	0	0	0	0
	Dec	0.57	0.26	0.62	0	1.07	0	0.53	0	0.27	0	0.36	0.27	0.92	0.47	1.53	0.51	0.27	0.24	0.17	0	127.56	6.89	0.47	3.28	1.78	1.52	0.64	0	0	0	0.32	0	0.24
	Jan	0.51	0.24	0.51	0	1.20	0	0.54	0	0	0.32	0.77	0.47	3.34	0.62	0.47	0.59	0.25	0.31	0.30	0	212.48	11.28	2.58	7.02	4.08	8.48	1.20	1.42	0	0.24	0.74	0	0
2001 - 2002	Feb	0.47	0	0.92	0	0.92	0	0.92	0	0	0	0.92	0.47	1.53	0.48	1.52	1.50	0	0.40	0	0	117.92	1.91	0	0.99	2.48	3.28	0	0.92	0	0	0.16	0.24	0
	Mar	1.07	0	1.50	0	1.44	0	1.92	0	0	0	0.3	0	0.42	0	1.35	1.26	0	0.43	0.32	0	41.70	0	0	0	0.38	0.38	0	0.58	0	0	0.44	0	0
	Apr	1.53	0	1.68	0	1.65	0.45	1.69	0	0	0	0	0	0	0	0.45	0.59	0	0.37	0.35	0	1.62	0	0	0	0	0	0	0	0	0	0	0	0
	May	2.25	0	1.58	0	1.62	0.41	2.58	0	0	0	0	0	0	0	1.36	0.72	0	0.42	0.45	0	0	0	0	0	0	0	0	0	0	0	0	0.45	0
	June	2.92	0	1.44	0	4.68	0.32	2.68	0.16	0	0	0	0	0	0	1.65	3.38	0	0.24	0.18	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0
	July	2.38	0	1.42	0	2.63	0	1.97	0	0	0	0	0	0	0	3.06	1.92	0	0.27	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0
	Aug	0.32	0	0.47	0	2.55	0	1.68	0	0	0	0	0	0	0	3.81	3.03	0	0.18	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	0.23	0	0.42	0	1.22	0	1.38	0	0	0	0	0	0	0	2.14	3.81	0.36	0.23	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0.28	0	0.47	0	1.62	0	1.53	0	0	0	0	0	0	0	1.49	1.26	0	0.36	0.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	1.34	0	1.27	0	1.38	0	1.60	0	0	0	0.38	0	0.23	0.26	0.77	1.35	0	0.30	0.26	0	5.68	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	1.37	0	1.23	0	1.52	0	1.38	0	0	0	2.10	0	0.49	1.53	0.45	1.52	0	0.28	0.29	0	77.52	3.72	0	2.91	1.79	1.28	0	0	0	0	0.30	0	0.20
	Jan	1.20	0	1.17	0	1.19	0	1.52	0	0	0	1.50	1.32	1.76	0	1.05	1.22	0	0.31	0.28	0	172.96	14.84	0	7.28	6.28	7.28	0	1.28	0	0	0.64	0	0.25

Table 5c Seasonal mean abundance (Ind/hectare) of dominant avifaunal species at S3 site Santragachi Jheel.

Year	Month	Dominant avifauna species																																
		Aru	Pfu	Pni	Aal	Bib	Ein	Agr	Nny	Aci	Apu	Rst	Ppo	Gch	Fat	Aph	Min	Hch	Aat	Hsm	Cru	Dja ◙	Aac	Acr	Ast	Acl	Aqu	Apl	Nco	Afo	Sme	Gga	Tst	Tgl
2000 - 2001	Feb	2.47	0	3.00	0	3.04	0.26	3.31	0.40	0	0.24	3.54	0.98	6.24	6.00	3.20	2.20	0.38	0.42	0.45	0.22	339.20	22.40	0.75	3.72	7.21	6.00	1.04	2.40	0	0	2.48	1.58	0.48
	Mar	2.70	0	4.04	0	3.30	0.41	4.08	0	0	0	0.54	0	2.48	1.48	2.42	2.82	0	0.38	0.36	0	138.12	4.20	0	0	1.52	0.46	0.18	2.24	0	0	0.78	0.30	0
	Apr	4.08	0.61	5.48	0	4.51	0.30	6.19	0.24	0	0	0	0	1.50	0	4.48	3.90	0	0.45	0.44	0	12.48	0	0	0	0	0	0	0	0	0	1.20	1.30	0
	May	3.24	0.24	4.14	0.31	5.28	0	7.84	0.42	0.25	0	0	0	0	0	4.38	4.58	0.64	0.74	0.47	0	0	0	0	0	0	0	0	0	0	0	1.14	1.24	0
	June	4.01	0.74	7.12	0.45	7.90	0	7.49	0.48	0.32	0	0	0	0	0	5.12	7.00	0.32	0.45	0.42	0.32	0	0	0	0	0	0	0	0	0	0	0.68	0	0
	July	1.51	0	4.84	0	3.24	0	5.68	0	0	0	0	0	0	0	8.28	7.70	1.58	0.18	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	1.44	0	2.42	0	2.25	0	5.00	0	0	0	0	0	0	0	8.38	8.28	2.14	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	1.18	0	2.40	0	2.10	0	4.42	0	0	0	0	0	0	0	8.00	7.35	3.00	0.20	0.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0.63	0.27	2.28	0	3.40	0.32	4.84	0	0	0	0	0	0.24	0	6.54	2.38	0.45	0.24	0.24	0	0	0	0	0	0	0	0	0	0	0	0.24	0.24	0
	Nov	0.93	0	1.04	0	3.48	0.30	2.41	0	0	0	0.32	0.48	1.32	0	2.28	1.54	0.60	0.23	0.25	0	12.48	0.78	0.24	1.52	0.37	0.46	0	0	0	0	0	0.76	0.46
	Dec	0.91	0.47	1.20	0	2.50	0.32	2.80	0.32	0.27	0.32	2.28	3.02	2.84	0.84	2.10	1.48	0.68	0.30	0.27	0.19	413.10	18.98	0.67	7.28	7.49	4.48	1.62	0	0	0.24	3.01	0.43	0.62
	Jan	0.96	0.45	0.92	0	2.82	0.38	2.92	0	0.62	0.41	4.58	4.02	9.20	1.28	1.38	1.20	1.58	0.25	0.30	0	671.25	23.48	7.17	16.24	19.00	20.14	1.84	10.12	0.18	0.45	3.28	0.30	0.38
2001 - 2002	Feb	1.20	0.35	1.84	0	3.30	0	3.28	0	0	1.80	3.84	3.68	5.70	1.54	3.20	4.00	2.24	0.42	0.45	0	337.54	6.84	0	3.54	6.28	7.28	0.54	4.60	0	0	1.82	1.32	0
	Mar	2.23	0	3.21	0	5.58	1.54	4.38	0.26	0	0	0.28	0	2.14	1.22	4.92	3.28	2.10	0.50	0.75	0	116.28	0	0	0	1.51	0.64	0	1.52	0	0	0.42	0.30	0
	Apr	2.756	0	3.28	0	4.28	1.78	4.84	0.30	0	0	0	0	0	0	4.02	2.28	0	0.48	0.39	0	1.84	0	0	0	0	0	0	0	0	0	0	0.70	0
	May	3.89	0	3.98	0	4.54	1.92	6.28	0.45	0	0	0	0	0	0	3.70	2.52	0	0.58	0.62	0.32	0	0	0	0	0	0	0	0	0	0	0	1.04	0
	June	4.86	0.37	5.76	0	7.69	3.24	7.90	0.48	0	0	0	0	0	0	4.48	5.80	0	0.40	0.38	0	0	0	0	0	0	0	0	0	0	0	0	1.92	0
	July	4.12	0	5.21	0	4.28	0.48	6.10	0	0	0	0	0	0	0	6.12	4.27	0	0.33	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0.48	0
	Aug	2.51	0	1.46	0	5.38	0.30	3.48	0	0	0	0	0	0	0	6.60	7.84	1.54	0.23	0.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	2.48	0	1.12	0	3.28	0	4.30	0	0	0	0	0	0	0	6.82	8.42	1.84	0.22	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	3.64	0	1.38	0	5.18	0.64	5.62	0	0	0	0	0	0	0	5.00	3.10	0.72	0.45	0.53	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	1.81	0	2.31	0	5.05	0	3.28	0	0	0	1.48	0	0.44	0.78	3.25	3.20	0.60	0.47	0.46	0	25.78	0.32	0	0	0	0	0	0	0	0	0.32	0	0.32
	Dec	2.01	0	2.14	0	4.21	0.36	3.08	0	0	0.30	4.68	0.73	2.66	4.48	2.18	4.84	0.84	0.30	0.32	0	247.28	16.28	0	4.52	4.60	3.10	0	0.26	0	0	0.78	0	0.45
	Jan	2.25	0	2.18	0	3.25	0.54	4.28	0	0	0.45	5.28	3.28	6.10	3.94	3.24	3.42	0.62	0.32	0.34	0.25	413.72	21.14	0	12.40	9.04	14.28	0	1.90	0	0	3.20	0	0.98

any regular patterns of variation in Santragachi Jheel. However, maximum density was recorded during June, 2001 at S_1 site (0.50 Ind/ha).

Anatidae

Family Anatidae was represented by 10 species. Some of them are migratory and others are resident migratory. The peak mean density of this family was observed (663.52 Ind/ha) during January, 2001. The mean density was higher at S_1 site than S_2 and S_3 sites.

The population density of *Dendrocygna javanica* was observed to be highest at S_1 site (829.13 Ind/ha) during January, 2001 (Table 5a). This species contributes almost 80% abundance of the family Anatidae. Peak density of *Anas acuta* was observed at site S_1 during January, 2001 (66.72 Ind/ha). In comparison to first year, the population density was decreased in second year, i.e., January, 2002. The population density of *Anas crecca* was higher at S_1 site (8.07 Ind/ha) during January, 2001. During the second year, i.e., winter season, 2002, this species was totally absent at all the three sites. The abundance of *Anas strepera* was lower at S_2 site than S_1 and S_3 sites in Santragachi Jheel. It showed the highest peak at site S_3 during January, 2001 (21.86 Ind/ha). Maximum density of *Anas clypeata* (19.00 Ind/ha) was observed at S_3 site during January, 2001. *Anas querquedula* abundance showed peak density (21.47 Ind/ha) at S_1 site during January, 2001. *Anas platyrhynchos* was absent at all three sites during the second year of observation i.e., January, 2002. It showed maximum abundance (2.54 Ind/ha) at S_1 site during February, 2000. The population of *Nettapus coromandelianus* showed peak density (10.12 Ind/ha) at S_3 site during January, 2001. *Anas formosa* is a rare bird species in India. It was observed only during January, 2001 (0.26 Ind/ha at S_1 site). *Sarkidiornis melanotos* was observed during January, 2001(0.45 Ind/ha at S_3 site).

Scolopacidae

Family Scolopacidae was represented by 3 species. The population density was highest during winter season. Highest mean population density was observed during January, 2001 (2.68 Ind/ha). The abundance of *Gallinago gallinago* was highest at S_3 site during January, 2001 (3.28 Ind/ha). The population density of *Tringa stagnatilis* was highest at S_3 site during June, 2001 (1.92 Ind/ha). Peak density of *Tringa glareola* was recorded at S_3 site during January, 2002 (0.98 Ind/ha).

Avifaunal community analysis in Santragachi jheel

In the present study, Shannon-Wiener diversity index (H′) of avifaunal community was observed to be highest (2.689) at S_1 site during the year 2000-2001 and lowest (2.098) at S_2 site during the year 2001-2002 in Santragachi Jheel. The species richness value was comparatively high (3.148) at S_1 site during 2000-2001 year and low (1.705) at S_2 site during 2001-2002 year in Santragachi Jheel. The evenness index of avifaunal community was found to be maximum at S_2 site (1.642) and minimum at S_1 site (1.028) in Santragachi Jheel (Table 6). Avifaunal coefficient of similarity (Sorensen's index of similarity) was maximum between S_1 and S_3 sites (80%) and minimum avifaunal similarity was observed between S_1 site (37%).

Statistical analysis

Multiple regression analysis between physico-chemical parameters and abundance (Ind/ha) of avifauna

Stepwise multiple regression analysis is applied to study about the physico-chemical parameters affecting the avifaunal abundance. Results of multiple regression analysis are presented in Table 7. In Santragachi Jheel, highest R^2 value related to Rallidae (0.9507**). The R^2 value showed for Anhingidae by conductivity, chloride and pH was 0.8569**. Nitrate and phosphate content of water explained 90% variation of Jacanidae population in Santragachi Jheel. Abundance of Anatidae was controlled simultaneously by two physico-chemical parameters i.e., dissolved oxygen and nitrate and explained 82% variability.

Multiple regression analysis between macrophytal biomass (gm. dry wt./m²) and abundance (Ind/ha) of avifauna

The result presented in Table 8 shows the influence of macrophytes on avifaunal abundance. In Santragachi Jheel, the R^2 value showed for Antidae by RFLP and Emergent was 0.8188**. Marginal macrophytes ex-

Table 6 Avifaunal community indices (Mean) of Santragachi Jheel.

INDEX	Avifaunal community Indices (Mean)							
	2000-2001				2001-2002			
	S1	S2	S3	Mean	S1	S2	S3	Mean
H′	2.689	2.148	2.294	2.377	2.348	2.098	2.100	2.153
d	3.148	1.842	2.442	2.447	3.004	1.705	2.372	2.360
e	1.028	1.548	1.204	1.260	1.314	1.642	1.418	1.458

H′ = Shannon - Wiener index of diversity
d = Margalef's species richness
e = Evenness index

Table 7. Stepwise multiple regression analysis between physico-chemical characteristics of water and avifaunal abundance (Ind/hectare) in Santragachi Jheel.

Avifauna	Physico-chemical parameters	Multiple regression values between physico-chemical parameters of water and avifaunal abundance				
		βj	SE βj	βo	SE βj	R^2
Total Avifauna	Total suspended solids (TSS)	-1.2091**	0.3211	154.8461**	38.9104	0.6643**
	Nitrate (NO_3)	3.9899*	0.6545			
Anhingidae	Conductivity (Con)	-0.0229**	0.0057	110.9215**	29.3349	0.8569**
	Chloride (Cl)	0.3823*	0.0469			
	pH	-14.1799**	3.5443			
Phalacrocoracidae	Temperature of water (WT)	1.3146**	0.2914	7.0841**	12.8231	0.8921**
	Total alkalinity (TA)	0.3308**	0.0651			
Ardeidae	Transparency (Tr)	-0.5067*	0.1934	6.9709**	1.6909	0.6366**
	Dissolved oxygen (DO)	-0.0114*	0.0019			
Rallidae	Total suspended solids (TSS)	-0.2776**	0.0495	483.3054**	56.2780	0.9507**
	Nitrate (NO_3)	3.6857**	0.7745			
Jacanidae	Nitrate (NO_3)	-2.0064**	0.5178	136.5152**	19.5887	0.9007**
	Phosphate (PO_4)	17.2487**	3.0947			
Anatidae	Dissolved oxygen (DO)	7.6365**	1.0561	-0.0664*	0.0111	0.8194**
	Nitrate (NO_3)	0.1184**	0.0271			
Scolopacidae	Total dissolved solids (TDS)	3.7784*	0.4351	-80.6837**	43.7241	0.9120**
	Dissolved oxygen (DO)	-6.8089*	2.4414			

$ß_j$ = Partial regression coefficient
$ß_0$ = Constant
SE = Standard error
R^2 = Coefficient determination
* : $p< 0.05$, ** : $p< 0.01$

Table 8. Stepwise multiple regression analysis between macrophytal biomass (gm.dry wt./m^2) and avifaunal abundance (Ind/hectare) in Santragachi Jheel.

Avifauna	Macrophyte category	Multiple regression values between macrophytal biomass and avifaunal abundance				
		βj	SE βj	βo	SE βj	R^2
Total Avifauna	Obligatory or partially submerged plants	-1.9402**	0.6758	5.9725*	3.4212	0.6529**
	Emergent	3.5621*	1.3628			
Anhingidae	Free floating	0.0323*	0.0089	8.1762**	3.7357	0.5379**
	Emergent	-0.0736**	0.0189			
Phalacrocoracidae	Free floating	0.0483*	0.0081	5.1866*	3.3684	0.6859**
	Emergent	-0.0688**	0.0171			
Ardeidae	Free floating	0.0795*	0.0142	21.3159**	5.9346	0.7091**
	Rooted floating leaved plants	-0.1581**	0.0301			
Rallidae	Marginal	-1.1753**	0.3864	275.8364**	79.8986	0.2960*
Jacanidae	Free floating	0.0396*	0.0104	-3.2423*	3.2999	0.3959*
lcedinidae	Emergent	-0.0172*	0.0037	3.7189*	0.5812	0.4939*
Antidae	Rooted floating leaved plants	-56.1553*	6.3162	4465.1380**	522.0331	0.8188**
	Emergent	24.2729*	5.1289			
Scolopacidae	Emergent	-0.0367*	0.0097	7.0761**	1.5157	0.3948*

$ß_j$ = Partial regression coefficient
$ß_0$ = Constant
SE = Standard error
R^2 = Coefficient determination
* : $p< 0.05$, ** : $p< 0.01$

Table 9. Stepwise multiple regression analysis between the abundance of macroinvertebrates (no/m^2) and avifauna (Ind/hectare) in Santragachi Jheel.

Avifauna	Macroinvertebrates	Multiple regression values between the abundance of macroinvertebrates and avifauna				
		βj	SE βj	βo	SE βo	R^2
Total avifauna	Oligochaeta	- 3.5249**	0.6061	58.0400**	14.2423	0.6677**
	Gastropoda	0.1147*	0.0205			
Anhingidae	Oligochaeta	-0.0839**	0.0179	15.6711**	1.9093	0.5418*
	Diptera	-0.0634**	0.0165			
Phalacrocoracidae	Ephemeroptera	-0.3953*	0.1314	15.9408**	2.3288	0.2915*
Ardeidae	Ephemeroptera	-0.9022*	0.2573	46.2637**	7.5394	0.3796*
	Hemiptera	-0.2408*	0.1082			
Rallidae	Hemiptera	-1.7409**	0.6745	166.1188**	37.1863	0.4080*
	Bivalvia	-14.1463*	4.7220			
Jacanidae	Ephemeroptera	-0.3868**	0.1257	15.1180**	2.2281	0.3009*
Alcedinidae	Hirudinea	-0.0298**	0.0126	1.1428*	0.4559	0.5206*
	Coleoptera	0.0173*	0.0058			
Anatidae	Odonata	15.3414**	5.2462	-946.5090**	136.5807	0.9618**
	Diptera	17.3386**	1.6202			
	Gastropoda	31.9089**	6.7672			
Scolopacidae	Oligochaeta	-0.0213*	0.0092	2.8359*	0.7139	0.1970*

$ß_j$ = Partial regression coefficient
$ß_0$ = Constant
SE = Standard error
R^2 = Coefficient determination
* : $p< 0.05$, ** : $p< 0.01$

plained only 29% variation of Rallidae abundance in Santragachi Jheel. Free floating and emergent plants jointly controlled 71% variation of Ardeidae abundance in Santragachi.

Multiple regression analysis between the abundance of macroinvertebrates (No/m^2) and abundance (Ind/ha) of avifauna

Results of multiple regression analysis for the presentation of avifaunal dependence on macroinvertebrates are presented in Table 9. Oligochaeta and Diptera explained 54% variation of Anhingidae abundance in Santragachi. R^2 value for Phalacrocoracidae by Ephemeroptera was only 0.2915* in Santragachi Jheel. Antidae was influenced jointly by Odonata, Diptera and Gastropoda (R^2 = 0.9618**) in Santragachi Jheel.

Discussion

Present studies reveal seasonal variability of avifaunal abundance in terms of Ind/ha in Santragachi Jheel. Total avifaunal abundance was correlated significantly with seasons in it. Bhupathy *et al.* (1998) pointed out the avifaunal population fluctuations in different seasons in Keoladeo National Park, Bharatpur, India. Cayford and Waters (1996), Devos and Ulenaers (1997) reported the winter maxima of avifauna in various water bodies which holds true for Santragachi Jheel during the present investigation.

It is well known that the water birds play a vital role as indicators of nutrient status of wetland ecosystem (Tamisier and Boudouresque 1994). A waterbody's trophic status is a major factor influencing species richness (Murphy *et al.* 1984, Brown and Dinsmore 1986). In Santragachi Jheel, avifaunal species richness was high. Species richness is increased in eutrophic lakes because productive lakes have greater food resources (Nilsson and Nilsson 1978, Hoyer and Canfield 1994). According to Somashekar and Ramaswamy (1984) larger value of the index of species richness denotes a more healthy body of water. In the present observation avifaunal species richness is high in Santragachi Jheel. This may be due to high nutrient level for birds in it.

Present study suggests that trophic status is the most important factor related to use of water bodies by avifaunal representatives. Selection of wetland by avifauna appears to be influenced by the trophic status of the wetlands. When a wetland is productive there is probably enough food for the avifauna. The importance of associations among avian species distributions and limnological characteristics of wetlands has been recognized (Hoyer and Canfield 1990, Kerekes 1990). Murphy *et al.* (1984) stated that physico-chemical characteristics of water bodies regulate the abundance of waterfowl. Hoyer and Canfield (1994) and Tere and Parasharya (2004) observed that sewage areas as well as productive ecosystem are able to support a greater number of birds. This finding corroborates with the present observation that the population density of different species of the family Anhingidae and Phalacrocoracidae is higher in sewage sites than nonsewage sites in both Santragachi Jheel. Wetzel (1975) pointed out that total dissolved nitrogen and phosphorus reflect the pond productivity. According to Savard *et al.* (1994) total dissolved nitrogen levels were usually associated positively with density of most bird species. Todhunter (1995) reported the limnological factors as the key factor of waterfowl aggregation in North American wetlands. According to Tuite *et al.* (1984) waterfowl abundance was affected by nitrogen and phosphate fluctuations of waterbodies. During the present investigation total avifaunal abundance as well as the population density of family Antidae has a positive correlation with nitrate and phosphate in Santragachi Jheel. Marcos *et al.* (1995) pointed out the lake hydrology as the cause of Scolopacidae abundance at Chozas Lagoon, North Spain. Different species under the family Ardeidae have greater population density at sewage sites of Santragachi Jheel. This high density of Ardeidae family occurred in the water body, i.e., Santragachi Jheel, receiving large inputs of phosphorus and nitrogen rich nutrients. High density of birds belonging to families Rallidae and Jacanidae in the sewage sites of Jheel may be attributed to increased eutrophication. The higher population density of other families, viz., Anatidae and Scolopacidae in Santragachi Jheel corroborates with the findings of Sillen and Solbreck (1977) and Hoyer and Canfield (1994).

Alvo *et al.* (1988) identified a positive relationship between waterfowl density and Secchi transpar-

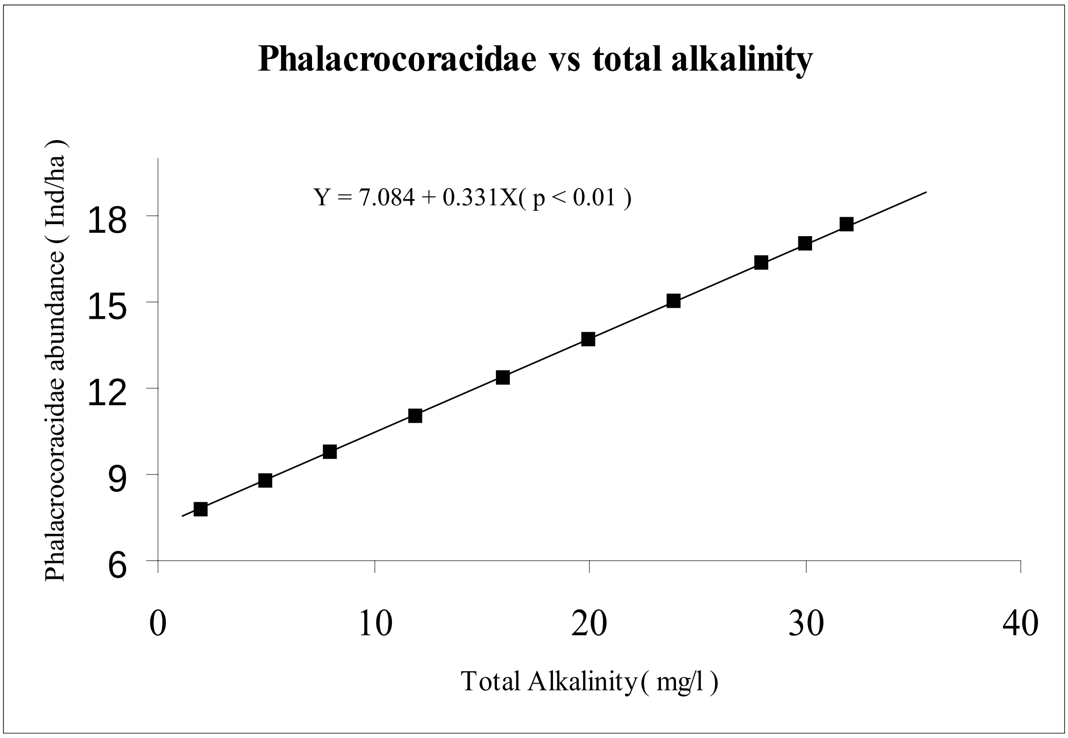

Fig. 1. Figure showing the regression relation between abundance (Ind/ha) of avifauna (Family: Phalacrocoracidae) and total alkalinity (mg/l) in Santragachi Jheel.

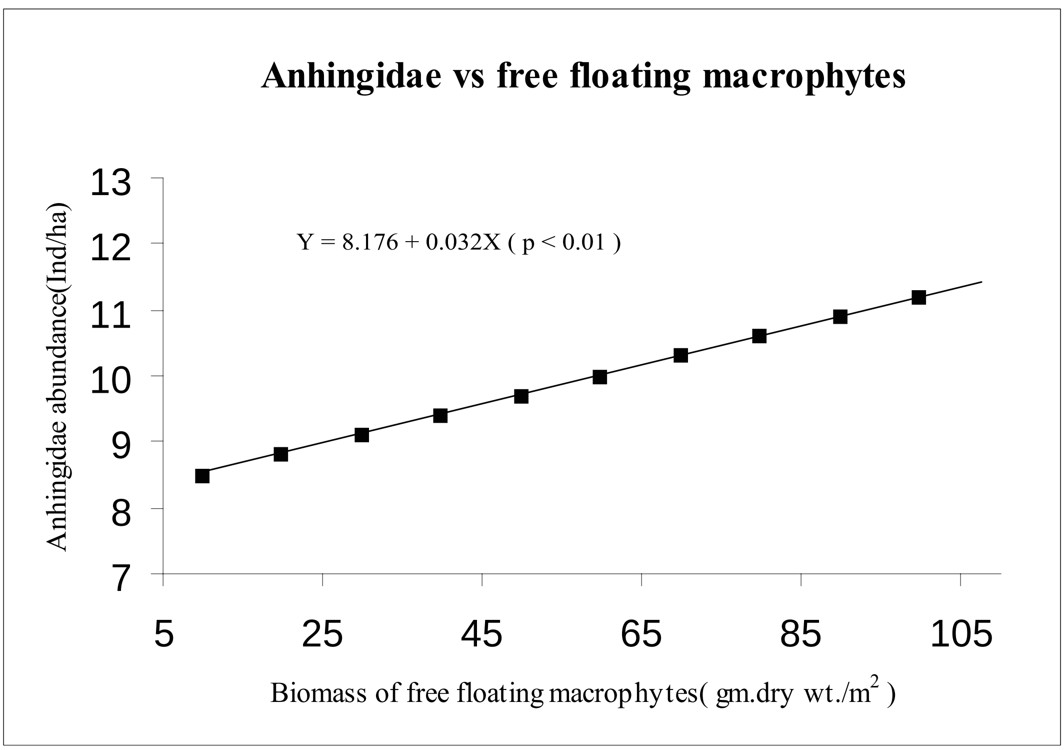

Fig. 2. Figure showing the regression relation between abundance (Ind/ha) of avifauna (Family: Anhingidae) and free floating macrophytes (gm.dry wt./m2) in Santragachi Jheel.

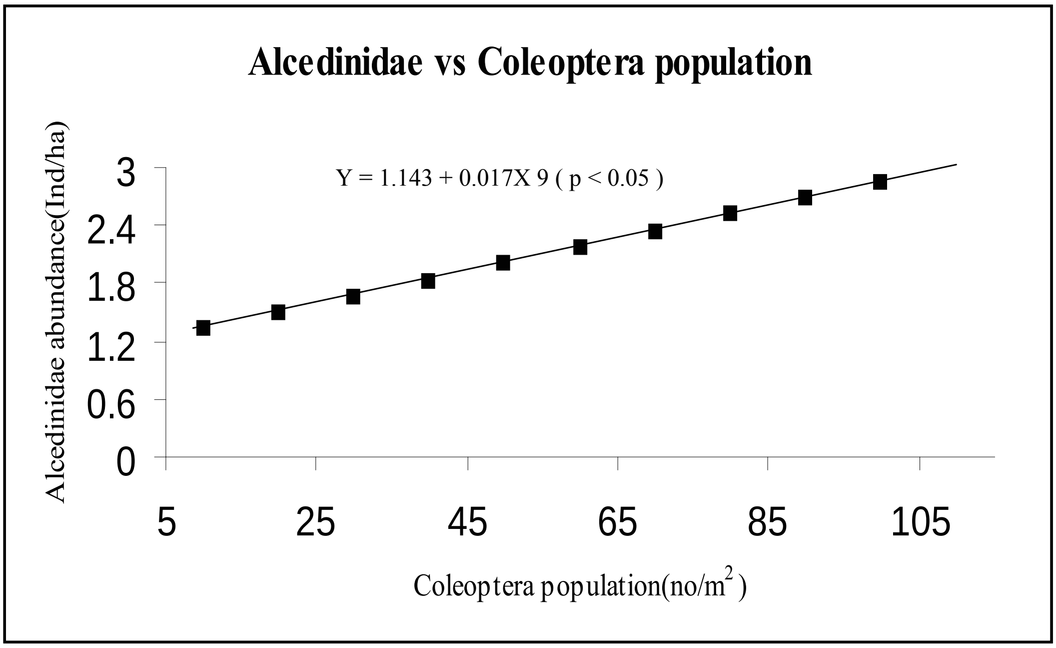

Fig. 3. Figure showing the regression relation between abundance (Ind/ha) of avifauna (Family: Alcedinidae) and Coleoptera population (no/m2) in Santragachi Jheel..

ency in lakes of Ontario, Canada. KEREKES (1990) found that birds have no preference to the transparency of water. However, in Santragachi Jheel family Phalacrocoracidae and Alcedinidae showed negative relationship with the transparency of water.

The degree of eutrophication is an index for the phosphorus content and thus for primary production. Using it in connection with waterfowl, it may be regarded as a variable integrating the feeding conditions. Theory predicting that more productive wetlands should have higher bird densities and species numbers is largely supported by many Ornithologists. NILSSON and NILSSON (1978) found positive correlations between nutrient content and waterfowl abundance for most avifaunal species. SUTER (1994) also reported that waterfowl densities were low in most nutrient loaded river dams than in more moderately polluted areas. In the present study a remarkable decline of winter avifaunal density at S_3 site (hypereutrophic zone) in Santragachi Jheel from winter season 2000-2001 to 2001-2002 supports this finding.

A suite of characteristics reflecting higher trophic status, from water quality to invertebrate and macrophytic biomass, were correlated with the avifaunal density (STAICER *et al.* 1994). Most statistical methods used to examine the species-environment relations have assumed normal distributions and linear associations. Although strong linear relations have been demonstrated among certain habitat characteristics and species use, work conducted on vegetation-environment gradients suggests the linear models may not adequately explain species-habitat relations without quadric or more complex terms (WHITTAKAR 1967, AUSTIN 1980, WEINS 1985). Total avifaunal density has been related positively ($P < 0.05$) with total macrophytic biomass in Santragachi Jheel. Aquatic macrophytes are important to bird populations that use water bodies and the management of aquatic macrophytes has the potential to affect bird populations. In the present study, population of Aantidae family is correlated ($P < 0.05$) with submerged macrophytes in Santragachi Jheel. Similar types of observations were found by RAVELING and HEITMEYER (1989). ALTHOUGH HOYER and CANFIELD (1994) reported that the removal of aquatic macrophytes from lakes may have no effect on annual average bird abundance (numbers or biomass) or total species richness. DE-SZALAY and RESH (1997) reported that controlled removal of macrophytes of lakes enhances the avifaunal density. In the present study Ardeidae and Jacanidae families were positively correlated with the free floating macrophytes in both Santragachi Jheel. Their population has been increased during summer months, i.e., breeding season. TALUKDAR (1996) reported the relationship between free floating vegetation and the population of *Metopidius indicus*. MCKINNON and MITCHELL (1994) also correlated the winter population of black swans with the biomass of macrophytes and constitute their food in a group of shallow lakes in New Zealand which span a wide range of size and trophic status. NELSON and KADLEC (1984) described the interactions occurring among macrophytes, macroinvertebrates and water birds in freshwater wetlands as a complex interdependency in which dynamic changes in the abundance and distributional pattern of macrophytes resulting from processes in litter decomposition and macroinvertebrate communities that, in turn, affect avifaunal abundance in water bodies. In the present study a clear positive correlation has been found between macroinvertebrates and avifaunal abundance in both Santragachi Jheel. In Santragachi Jheel the population of adult Jacanidae and Rallidae followed by the juveniles were related positively with the macroinvertebrate food contents. Carter (1976) reported the positive relationship between waterfowl and Chironomidae (Diptera) population of Lough Neagh, Northern Ireland. Similar types of observations were found between Diptera and avifaunal abundance in Santragachi Jheel. GOLE (1983) also pointed out the positive relationship between bird population and organic enrichment of waterbody. According to MARION *et al*. (1994) birds play small role in eutrophication of hypereutrophic Lake Grand-Lieu, France. They reported that the role of birds in total input of nitrogen and phosphorus is small due to human sewage inputs. In the present observation also in Santragachi Jheel with heavy human sewage input, the winter migrant Anatidae population as well as total avifaunal population was positively correlated ($P < 0.05$) with phosphate content of water. The sharp rise of phosphate content of water at S_1 site (high avifaunal density) during winter season, 2000-2001 seems to be due to avifaunal defecation as well as the addition of guano. PAULRAJ (1988) also established an inverse relationship between avifaunal density and transparency of water. Though a significant relationship was not observed between the transparency and avifaunal density in Santragachi Jheel, but a sharp decline of transparency value of water of different sites was observed with the arrival of migratory birds. The transparency of water decreased promptly due to constant addition of guano and birds movement (PAULRAJ, 1988).

Birds aggregation is related with various factors, e.g. limnological, macrophytal, macroinvertebrate and other physical factors of Jheel. Birds usually prefer the productive nature of the wetland. But they avoid very much productive i.e., polluted areas of water bodies, as evidenced in S_3 site of Santragachi Jheel where the avifaunal population was decreased in the winter of the year 2001-2002 in comparison to the year 2000-2001. Submerged macrophytes have a positive impact on avifaunal abundance. Birds belonging to the family Jacanidae are closely related with free floating macrophytes for their food as well as breeding ground. The population of some macroinvertebrate faunal dependent birds is increased proportionately with the abundance of macroinvertebrates. It is well known that the guano of bird is rich with nitrate and phosphate. So, the present studies on avifaunal population show a positive relationship with these two nutrient factors in Santragachi Jheel.

Acknowledgement: We are indebted to Dr. Premadhis Das, Professor in Statistics, University of Kalyani and Dr. Debasis Chatterjee, Scientist, Indian Statistical Institute, Kolkata for extending their kind assistance in statistical analysis. We are thankful to Scientists of Zoological Survey of India and Botanical Survey of India for helping in identification of specimens. Our grateful thanks are extended to the Soil Chemistry Laboratory, Bidhanchandra Krishi Viswavidyalaya, Mohanpur, Nadia, W.B. for offering the water testing facilities.

References

ALI S. 1933. The Hyderabad state ornithological survey. – *J. Bom. Nat. Hist. Soc*., **40:** 497-499.

ALI S. 1963. Pt. Calimere as a refuge for wintering shore birds. – *J. Bom. Nat. Hist. Soc*., **60**: 458-460.

ALI S. 1996. The book of Indian birds. London. Oxford Univ. Press, 298 p.

ALI S. and S. D. RIPLEY 1983b. A Pictorial Guide to the Birds of the Indian Subcontinent. Oxford Univ. Bomay, India, Press, pp. 165.

ALVO R. D., J. T. HUSSE and BERRILL M. 1988. The breeding success of common loons (*Gavia immer*) in relation to alkalinity and other lake characteristics in Ontario. – *Can. J. Zool*., **66:** 746-752.

Anonymous 1998. Project: Pictorial directory of common wetland and aquatic flora of West Bengal. Department of Environment, Govt. of West Bengal, India, pp. 128.

APHA 1989. Standard Methods for the Examination of Water and Wastewater. Washigton, D. C. 17th edition American Public Health Association, 1093 p.

Austin M. P. 1980 Searching for a model for use in vegetation analysis. – *Vegetatio*. **42:** 11-21.

Barman R., P. Saikia, H. J. Singha, B. K. Talukdar and P.C. Bhattacharjee 1995. Study on the population trend of waterbirds at Deeper Beel Wildlife Sanctuary. – *Pavo*., **33** (1-2): 25-40.

Bhupathy S., V. S. Vijayan and R. Mathur 1998. Population ecology of migratory waterfowl in Keoladeo National Park, Bharatpur. – *J. Bom. Nat. Hist. Soc*., **95** (2): 287-294.

Biswas K. and C. C. Calder 1955. Handbook of common water and marsh plants of India and Burma – 1936. Health Bulletin. No. 24. Manager of publications, Delhi, pp. 216.

Brown M. and J. J. Dinsmore 1986. Implications of marsh size and isolation for marsh bird management. – *J. Wildl. Mgmt*., **50**: 392-397.

Carter C. E. 1976. A population study of the Choronomidae (Diptera) of Lough Neagh. – *Oikos*., **27**: 346-354.

Cayford J. T. and R. J. Waters 1996. Population estimates for waders Charadri wintering in Great Britain, Norfolk IP24 2PU, U.K. – *Biol. Conserv*., **77** (1): 7-17.

Chakraborty K. 1982. A statistical investigation on the Wildlife census and monitoring. – *Proc. Sym. Ecol. Anim. Popul. Zool. Surv. India*., **4:** 147-152.

De (Pal), M. and T. Sengupta 1993. Beetles (Coleoptera: Insecta) of wetlands of Calcutta and its surroundings. – *Rec. zool. Surv. India*., **93** (1-2): 103-138.

DesGranes J. L. 1989. Studies of the effects of acidification on aquatic wildlife in Canada: lacustrine birds and their habitats in Quebec. – *Can. Widl. Ser. Occas. Pap.*, **67:** 112-129.

De-Szalay F. A. and V. H. Resh 1997. Responses of wetland invertebrates and plants important in waterfowl diets to burning and mowing of emergent vegetation. *Wetlands*., **17** (1): 149-156.

Deuti K. 2000. The Baikal Teal and its incidence in West Bengal. – *Twilight.*, **2** (2-3): 48-50.

Deuti K. A. Halder A. Das and D. K. Biswas 1998. Baikal Teat at Tilpara Barrage, West Bengal. *Bird Watchers*., **38** (1): 11-12.

Devos K. and P. Ulenaers 1997. Increase of wintering and migrating cormorants *Phalacrocorax carbo* in Flanders, Belgium. – *Ekol. Polska*., **45** (1): 47-49.

Dobrowolski K. A. R. Halba and J. Nowicki 1976. The role of birds in eutrophication by import and export of trophic substances of various waters. – *Limnologica.,* **10**: 543-549.

Emlen J. T. 1971. Population densities of birds derived from transect counts. – *Auk.* **88:** 323-342.

Franzreb K. E. 1981. The determination of avian densities using the variable strip and fixed-width transect surveying methods. In Estimating numbers of territorial birds. – *Stud. Avian Biol*., (Eds.: Ralph, C. J. and Scott, J. M.). **6:** 139-145.

Gere G. and S. Andrikovics 1992. Effects of waterfowl on water quality. – *Hydrobiologia.*, **243/244:** 445-448.

Ghosh A. K. 1990. Biological resources of wetlands of East Calcutta. *Ind. J. Landsc.*, – *Syst. Ecol. Stud.*, **13** (1): 10-23.

Ghosh A. K. and S. Chattopadhay 1990. Biological resources of Brace Bridge wetlands. – *Ind. J. Landsc. Syst. Ecol. Stud*., **13** (2): 189-207.

Ghosh A. K. and S. Chattopadhay 1994. Biological resources of periurban wetlands: Santragachi Jheel, Howrah district, West Bengal. – *Ind. J. Landsc. Syst. Ecol. Stud.*, **17** (1): 1-7.

Gole P. 1983. Birds of a polluted river. – *J. Bom. Nat. Hist. Soc*., **81:** 613-625.

Golterman H. L. (Ed.) 1969. Methods of chemical analysis of freshwaters. IBP Handbook No. 8, Blackwells, Oxford, pp. 172.

Gremillion P. T. and R. F. Malone. 1986. Waterfowl waste as a source of nutrient enrichment in two urban hypereutrophic lakes. – *Lake and Res. Mgmt*., **2**: 319-322.

Havgaard P. 1973. A new system of sieves for benthic samples. – *Sarsia.*, **53:** 15-18.

Heglund P. J., J. R. Jones, L. H. Frederikson and M. S. Kaiser 1994. Use of boreal forested wetlands by Pacific loons (*Gavia pacifica* Lawrance) and horned grebes(*Podiceps auritus* L.): relations with limnological characteristics. – *Hydrobiologia.*, **279/280:** 171-183.

Hoyer M. V. and Jr. D. E. Canfield 1990. Limnological factors influencing bird abundance and species richness on Florida lakes. – *Lake Reserv. Mgmt*., **6:** 132-141.

Hoyer M. V. and Jr. D. F. Canfield 1994. Bird abundance and species richness on Florida lakes: influence of trophic status, lake morphology and aquatic macrophytes. – *Hydrobiologia*., **279/280:** 107-119.

Jayaram K. C. 1981. A handbook of the freshwater fishes of India, Pakistan, Bangladesh, Burma and Sri Lanka. Zool. Surv. India, Calcutta, pp. 475.

Kerekes J. 1990. Possible correlation of summer common loon (*Gavia immer*) population with the trophic state of a waterbody. – *Verh. Int. Ver. Limnol*., **24:** 349-353.

Kumar V. V. and B. C. Choudhury 1994. A report on waterfowl study in Manjira Wildlife Sanctuary, Andhra Pradesh, India and its implication in long-term management of this sanctuary. – *Pavo*., **32** (1-2): 47-57.

Lillie R. A. and J. O. Evrard 1994. Influence of macroinvertebrates and macrophytes on waterfowl utilization of wetlands in the Prairie Pathole Region of northwestern Wisconsin. – *Hydrobiologia*., **279/280:** 235-246.

Manny B. A. W. C. Johnson and R. G. Wetzel 1994. Nutrient additions by waterfowl to lakes and reservoirs: predicting their effects on productivity and water quality. – *Hydrobiologia*., **279/280:** 121-132.

Marcos J. M., T. Velasco and L. J. Alberto 1995. Population structure and phenology of waders at Chozas Lagoon, Leon Province (N Spain). – *Misc. Zool*., **18:** 161-168.

Margalef R. 1958. Information theory in Ecology. – *Gen. Syst.* **3:** 36-71.

Marion L. P. Clergeau, L. Brient and G. Bertru 1994. The importance of avian contributed nitrogen (N) and phosphorus (P) to Lake Grand-Lieu, France. – *Hydrobiologia.*, **279/280:** 133-147.

McIntyre J. W. 1988c. Water level fluctuation and Common Loon productivity on the Stillwater Reservoir. Report for Stillwater Ass. Albany, N.Y. p.13.

McKinnon S. L. and S. F. Mitchell 1994. Eutrophication and black swan (*Cygnus atratus* Lathan) populations: tests of two simple relationships. – *Hydrobiologia.* **279/280:** 163-170.

McNicol D. K. and M. E. Wayland 1992. Distribution of waterfowl broods in Sudbury area lakes in relation to fish, macroinvertebrates and water chemistry. – *Can. J. Fish. aquat. Sci.*, **49** (Suppl. 1): 122-133.

Michael P. 1984. Ecological methods for field and laboratory investigations. New Delhi. Tata – McGraw Hill Pub. Com. Ltd., 1-404.

Mukherjee A. 1975. Food habits of waterbirds of the Sundarban, 24 Pgs., W. B., India. – *J. Bom. Nat. Hist. Soc*., **72** (2): 422-449.

Mukherjee A. 1976. Food habits of waterbirds of the Sundarban, 24 Pgs., W. B., India. – *J. Bom. Nat. Hist. Soc*., **73** (3): 482-486.

Murphy S. M. B. Kessel and L. J. Vining 1984. Waterfowl populations and limnological characteristics of taiga ponds. – *J. Wildl. Mgmt.*, **48:** 1156-1163.

Nandi N. C., S. R. Das, S. Bhunya and J. M. Dasgupta 1993. Wetland faunal resources of West Bengal. 1. North and South 24 Parganas District. – *Rec. Zool. Surv. Ind. Occ. Pap.*, **150:** 1-50.

Natarajan V. 1991. Wintering waterbirds at Point Calimere, Tamil Nadu. – *J. Bom. Nat. Hist. Soc.*, **89:** 316-328.

Nelson J. W. and J. A. Kadlec 1984. A conceptual approah to relating habitat structure and macroinvertebrate production in freshwater wetlands. – *Trans. N. Am. Wildl. Conf.*, **49:** 262-270.

NEWS 1998. Wetlands and waterbirds of West Bengal. Calcutta, Vision Publications Pvt. Ltd., 1-199 p.

Nilsson, S. G. and I. N. Nilsson 1978. Breeding bird community densities and species richness in lakes. – *Oikos*., **31:** 214-221.

North M. R. M. R. Ryan 1989. Characteristics of lakes and nest sites used by yellow-billed loons in Arctic Alaska. – *J. Field Ornithol.*, **60:** 296-304.

Pal S. and N. C. Nandi 1997. A simple device for quantitative sampling of macrofauna from littoral macrophytes. – *J. Freshwat. Biol*., **9** (3-4): 114-121.

Palmgren P. 1936. Uber die Vogelfauna der Binnengewasser Alands. Acta – *Hydrobiologia*., **17:** 1-59.

Parsons J. K. and R. A. Matthews 1995. Analysis of the associations between macroinvertebrates and macrophytes in a freshwater pond. – *Northwest Science*., **69** (4): 265-275.

Patra, A. K. B. Santra and C. K. Manna. 2010. Limnological studies related to physico-chemical characteristics of water of Santragachi and Joypur Jheel, W. B., India. – *Our nature*. 8. (In Press).

Patterson J. H. 1976. The role of environmental heterogeneity in the regulation of duck populations. – *J. Wildl. Mgmt*., **40:** 22-32.

Paulraj S. 1988. Impact of guano deposition in Vedanthangal water-bird Sanctuary (Chengalpattu District, Tamil Nadu). – *J. Bom. Nat. Hist. Soc*., **85:** 319-324.

Pielou E. C. 1966. The measurement of diversity on different types of biological collections. – *J. Theo. Biol*., **13:** 131-144.

Prakash V. 2000. Wintering in an oil refinery. – *Hornbill.*, 4-8.

Prakash V. and U. P. Sharma 1995. Feeding behaviour of birds of Kawar Lake Wetlands, in relation to population density of aquatic macrophytes, molluscs, insects and fishes. – *Proc. Con. Ornit. Soc. India.*, 69-70.

Prashant J. J., V. VasudevaRao and V. Nagulu 1994. Checklist of waterbirds in two different habitats in Nellore Dist., Andhra Pradesh. – *Pavo*., **32** (1-2): 63-66.

Rai D. N. and U. P. Sharma 1991. Co-relation between macrophytic biomass and macroinvertebrate community structure in wetlands of North-Bihar. – *Int. J. Ecol. Environ. Sci.*, **17:** 27-36.

Raveling D. G. and M. E. Heitmeyer 1989. Relationship of population size and recruitment of Pintails to habitat conditions and harvest. – *J. Wildl. Mgmt*., **53:** 1088-1103.

Sammaiah C. and J. L. Singh 2004. Species diversity of water birds as a pollution indicator. – *Proc. Int. Con. on Bird and Environment*, Haridwar, India. p. 59.

Savard J. L., W. SeanBoyd and G. E. JohnSmith 1994. Waterfowl-wetland relationships in the Aspen Parkland of British Columbia: Comparison of analytical methods. – *Hydrobiologia.*, **279/280:** 309-325.

Shannon C. E. and W. Wiener 1949. The mathematical theory of communication. Urbana.University of Illinois Press, p. 117.

Sillen B. and C. Solbreck 1977. Effects of area and habitat diversity on bird species richness in lakes. – *Ornithol. Scand*., **8:** 185-192.

Simpson E. H. 1949. Measurement of diversity. – *Nature*., **163:** p. 688.

Somashekar R. K. and S. N. Ramaswamy 1984. Biological assessment of water pollution- A study of river Kapila. – *Int. J. Environ. Stud*., **23:** 261-267.

Sorensen T. A. 1948. A method of establishing groups of equal aptitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. – *K. dan. Vidensk. Selsk. Biol. Skp*., **5:** 1-34.

SPSS 1993. Version-6.0. for Windows. SPSS, Chicago, Illinois, USA.

Srinivasulu B. C. Srinivasulu, V. Nagulu, V. VasudevaRao and C. Koteshwarulu 1996. Avifauna of selected waterbodies in northern suburb of Secunderabad, Andhra Pradesh. – *Pavo*., **34** (1-2): 87-94.

Srivastava V. D. 1993. Fauna of West Bengal, Insecta *:* Odonata. State Fauna Series. – *Zool. Surv. India, Calcutta.*, **3** (4): 51-168.

Staicer C. A. B. Freedman, D. Srivastava, N. Dowd, J. Kilgar, J. Hayden, F. Payne and T. Pollock 1994. Use of lakes by black duck broods in relation to biological, chemical and physical features. – *Hydrobiologia*., **279/280:** 185-199.

Subba Rao N. V. 1989. Handbook Freshwater Molluscs of India. – *Zool. Surv. India, Calcutta*., p.189.

Suter W. 1994. Overwintering waterfowl on Swiss lakes: how are abundance and species richness influenced by trophic status and lake morphology? – *Hydrobiologia*, **279/280:** 1-14.

Swanson G. A. and M. I. Meyer 1977. Impact of fluctuating water levels on feeding ecology of breeding blue-winged teal. – *J. Wildl. Mgmt.*, **41:** 426-433.

Talukdar B. K. 1996. Diversity of water birds in Pabitora wildlife Sanctuary. – *Pavo*., **34** (1-2): 17-21.

Tamisier A. and C. Boudouresque 1994. Aquatic bird populations as indicators of seasonal nutrient flow at Ichkeul Lake, Tunisia. – *Hydrobiologia*., **279/280:** 149-156.

Tere A. and B. M. Parasharya 2004. Importance of sewage pond for avifauna and some conservation issues. – *Proc. Int. Con. on Bird and Environment*, Haridwar, India. p. 61.

Todhunter P. 1995. Hydroclimatic perspectives on waterfowl production in the North Dakota Praire Pothole Region. – *Great Plains Res*., **5** (1): 137-162.

Tonapi G. T. 1980. Freshwater animals of India: An ecological approach. Calcutta. Oxford and IBH Publishing Co. New Delhi, Bombay, p. 341.

Trivedy R. K. J. M. Garud, P. K. Goel 1985. Studies in chemistry and phytoplankton of a few fresh water bodies in Kolhapur with special reference to human activity. – *Poll. Res.*, **4:** 25-144.

Tuite C. H. P. R. Hanson and M. Owen 1984. Some ecological factors affecting winter waterfowl distribution on inland waters in England and Wales, and the influence of water based recreation. – *J. Appl. Ecol*., **21:** 41-62.

Weins J. A. 1985. Habitat selection in variable environments. – In Habitat selection in birds. (Ed.): Cody M. L. Florida. Academic Press, Inc. Orlando, p.558.

Welch P. S. 1948. Limnological Methods. Blakiston Co. Philadelphia. p.381.

Wetzel R. G. 1975. Limnology. W. B. Saunders Company, Philadelphia, London and Toronto. W. B. Saunders Company, 743 p.

Whistler H. 1941. Popular hand book of Indian Birds. Gurney and Jackson, London.

Whittakar R.H. 1967. Gradient analysis of vegetation. – *Biol. Rev. Camb. Phil. Soc*., **49:** 207-264.

Woodcock M. 1986. Collins Hand guide to the birds of Indian subcontinent. London. Collins, 176 p.

Wright D. H. 1983. Species-energy theory: an extension of species-area theory. – *Oikos.*, **41:** 496-506.

WWF-India 1998. Waterfowl identification manual. (Ed.: Banerjee S. R.). 1-38.

Received: 26.04.2010
Accepted: 21.09.2010

Връзка между богатството и разнообразието на водни птици, макрофити, макробезгръбначни и физико-химичните характерисктики в Сантрагачи Джиил, Западна Бенгалия, Индия

А. Патра, К. Б. Сантра, Ч. К. Манна

(Резюме)

Изследването цели изучаване на разнообразието на фауната на птиците в Сантрагачи Джиил. Популацията показва различна сезонна динамика. Общо 33 вида, принадлежащи към 8 семейства и 23 рода са регистрирани и категоризирани като постоянно гнездещи, гнездещи мигриращи и мигриращи птици. Устанавена е максимална плътност на популацията през зимата. Сем. Anhingidae, Phalacrocoracidae и Ardeidae показват предмусоннен максимум във всички местообитания (S_1, S_2 и S_3) в Джиил. Богатството на сем. Rallidae и Anatidae е по-голямо през зимата, докато плътността на сем. Jacanidae е най-голяма през предмусонния период. Регистрирани са високи стойности на индекса Shannon-Wiener за разнообразието и богатството по Margalef за птичата фауна. Най-висока стойност на сходство е наблюдавана при местообитания S_1 и S_3. Богатството на птици е ясно свързано с разнообразните физико-химични параметри на водата, макрофитите, макробезгръбначните и други физични фактори на Джиил. Общото богатсво на птиците е положително повлияно от разтворения кислород (DO) и NO_3. Сем Ardeidae показа положителна корелация в температурата на водата (WT). Anatidae показва положителна връзка с NO_3. Ardeidae има добра положителна карелация със свободно плаващите макрофити. Сем. Jacanidae е положително повлияно от общите макрофити (T-MACP) и свободно плаващите макрофити (FF). Птичата фауна е повлияна от богатството на макробезгръбначните. Сем. Rallidae и Anatidae показват положителна корелация с ракообразните. Anatidae има положителна връзка с Diptera и Gastropoda.

Популацията на птиците в Сантрагачи Джиил варира сезонно при различните местообитания. Установена е връзка между плътността на птиците и трофичните характеристики, особено със съдържанието на фосфати.