1. INTRODUCTION

The term wetlands is used for such diverse habitats in different climatic zones of earth that it is indeed difficult to define it in simple terms. The situation is further complicated by the fact that whereas ecologists use the term “wetland” for ecosystems with specific ecological characteristics which differentiate them from other ecosystems, the conservationists insist on including a wide range of aquatic habitats (from temporary ponds to large deep water lakes and reservoirs, from small streams to large rivers and estuaries as well as coastal water and coral reefs).

Ramsar Convention on Wetlands defines wetlands as “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters” (Ramsar Convention Bureau 1987; Article 1.1). Further, the Convention defines that wetlands “may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands” (Article 2.1). With the increasing concern for global biodiversity values of the wetland habitats, Government of Nepal has endorsed National Wetland Policy (2003). It defines wetlands as “natural or artificial created areas, such as swamp, marsh, riverine floodplain, lake, water storage area and agricultural land containing water from underground water resources or atmospheric precipitation that may be permanent or temporary, static or flowing, freshwater or saline”. This is the first concrete approach taken by the Government of Nepal to wetland biodiversity conservation for the future.

Nepal’s wetlands covers approximately 743500 hectares of land cover that ranges from Terai to Himalayas including rivers, streams, lakes, ponds, swamps, marshes, reservoirs and paddy fields (DOAD, 1992). There are well over 405 wetlands in Nepal (Shrestha 1993). Among them 163 wetlands occur

in Terai, 164 in Midhills and 78 in high Himalayas (Shrestha 1993). The country has approximately 6000 rivers and rivulets, including permanent and seasonal rivers, streams and creeks (WECS, 2002). These contribute to the diverse range of wetlands in lowland Nepal. Considering the global significant values of Nepal's wetlands, some of the country's wetlands are listed as Wetlands of International Importance under the Ramsar Convention. Koshi Tappu Wildlife Reserve (1987), Beeshazari Taal (Lake) (2003), Ghodaghodi Lake (2003) and Jagadishpur Reservoir (2003) were included in the Ramsar lists.

Nepal's wetlands are facing tremendous anthropogenic pressure. Human induced activities such as deforestation, destructive means of wetland resources collection (e.g., fishing, gravel and driftwood collection) and water drainage for irrigation are the activities with the largest impact for the deterioration of wetland habitats (IUCN 2004, Bhandari 1998), which can greatly influence the structure of bird community (Francl and Schnell 2002). In addition to this, wetlands are widely covered by Invasive Alien Plant Species (hereafter IAPS). The term invasive alien plant species refers to a subset of those plant species defined as introduced species or non-indigenous species. IAPS can alter ecological relationships among native plant species and can affect ecosystem function, economic value of ecosystems, and human health. A species is regarded as invasive if it has been introduced by human action to a location, area, or region where it did not previously occur naturally, becomes capable of establishing a breeding population in the new location without further intervention by humans, and spreads widely throughout the new location (Cassey *et al.* 2005). Natural range extensions are common in many species, but the rate and magnitude of human-mediated extensions in these species tend to be much larger than natural extensions, and the distances that species can travel to colonize are also often much greater with human agency (Cassey *et al.* 2005).

Nepal's wetlands have heavily suffered from invasive alien plant species, primarily Water Hyacinth (*Eichhornia crassipes*). This alien species is native to Brazil and has become widespread on a global scale (Gopal 1987). It was first reported in Nepal in 1966 and is now widely distributed in most of the terai's protected areas (ranging from 75m to 1500m) of Nepal (Tiwari *et. al.* 2005).

Many researchers (Gopal 1987, Grodowitz 1998, Madsen 1997) found that water hyacinth plants have a tremendous growth and reproductive rate and the free-floating mats cause great problems for wetland biodiversity. Because of its highest growth rate, it rapidly expanded its coverage in most parts of the Beeshazari Taal resulting in heavy loss in biodiversity primarily for avian biodiversity. The aggressive expansion of water hyacinth significantly reduced open water area and caused sharp decline in number of pure water dwelling birds especially darters, cormorants and coots. The substantial coverage of water hyacinth can lead low dissolved oxygen levels that might influence the community dynamics of the benthic community (Gopal 1987) and ultimately to bird species that are dependent on insects and fishes. On its decomposition, the weed, being an organic material shall make use of oxygen from the lake, thus reducing or depleting the concentration of dissolved oxygen in the water. This will endanger the lives of the species of fish that have little tolerance for reduced oxygen levels. There are scientific evidences that the water hyacinth is capable of accumulating heavy metals, phenols, and toxic substances. Thus, sinking and eventual degradation of the weed shall result in an abrupt increase of toxic chemicals in the lake, which shall play havoc with the ecosystem. The decomposition of the water hyacinth will also enhance the eutrophication of the lake with serious consequences for the ecosystem, in addition to the increased likelihood of the regeneration of the water hyacinth (Odhiambo 1999).

Another most damaging exotic species is American (Southern) Cutgrass (*Leersia hexandra*). American Cutgrass is a grass and its stems are wiry and leaning, grow up to 4 feet long having nodes. It is hairy and rooting at nodes; leaf blades are flat, thin, tapering to a point with their margins sharp and rough on both sides of width up to 3/4 inches and 12 inches long. Flowers crowded toward branch tips to 3/16 inches long, stiff short hairs. It grows along the margins of marshes, streams, ponds, lakes, swamps, ditches and canals. *Leersia hexandra* sometimes forms floating islands and can grow in water up to 1.8m deep (Godfrey and Wooten 1979). Its dense mats along shorelines and in shallow water areas can restrict assess and hinder recreational activities. The plant can be a weed in rice fields and slow flow in irrigation canals. Prolific expansions of this species over the lake area of Beeshazari Taal prevent almost any open water surface in lake. This species can bring up the succession of the lake into agricultural land on the long term. Invasive alien plant species and effects are the worldwide problems and are increasingly recognized as representing a major threat to the preservation of biodiversity (Schnitz et. al. 1997).

Nepal is globally renowned for its high bird diversity and considered as a paradise for birds. A high total of 862 species have been recorded, occupying 8% of world's known birds (Baral and Inskipp 2004). The topography, rainfall, altitudinal variation together with the bio-geographical location of Nepal at the meeting point of the oriental and Palaearctic realms are major factors that contribute to the country's high avian diversity. Of the 862 bird species, an alarming number of 133 (15%) of Nepal's birds are considered nationally threatened and as many as 72 of these are thought to be critically threatened or endangered at a national level (Baral and Inskipp, 2004). A total of 44 nationally threatened birds are wetland species (Baral and Inskipp, 2004). Nearly half of the country's globally threatened birds (14 species) and near-threatened birds (10 species) regularly inhabit wetlands (Baral and Inskipp, 2005).

Water birds, both migratory and non-migratory, are important components of the biodiversity of wetland throughout the world (Davidson and Delany 2000). The degradation of wetland habitat has direct effect to faunal diversity including wetland birds. The loss of wetland habitat, globally, is of prime concern and is the major driving force for developing a conservation strategy (Denny 1994). The alarming statistic of wetland losses has a proportionally greater consequence on loss of global biodiversity, species richness and gene pools (WCMC 1992). The diminishing of useable vegetative areas reduces the food availability and suitable breeding areas for birds (Francl and Schnell 2002).

Birds are good indicators and useful models for studying a variety of environmental problems (Urfi *et. al.* 2005) because they potentially detect aspects of wetland landscape conditions that are not detected by other groups commonly used as indicators (USEPA 2002). Many previous studies have looked on wetland biodiversity (BPP 1995, Bhandari 1998, Sah 1997) but a few studies investigated particularly on wetlands birds (Inskipp and Inskipp 1991, Baral 1998, Gyawali 2003, Hungden and Clarkson 2003) in Nepal. Theses research studies were largely focused on species specific and baseline approaches and did not take into account the effect of the invasive alien plant species on the community structure of wetland birds since the concern in invasion of wetlands was very recent for Nepal. Although some short-term observations have been made for the qualitative description of the impact on biodiversity (Baral 2002, Baral and Inskipp 2004), these do not provide adequate information because the study was mainly focused on the state of birds of Nepal rather than effects of invasive alien plant species on wetland birds.

This study has been carried out in the Beeshazari Taal, a Ramsar site in the Central region of Nepal aiming to access the status of wetland birds in relation to the extent of invasion by invasive alien plant species. It is hoped that this

work will serve as a baseline study for the future research and monitoring of wetland birds in Nepal.

Limitations of the Study

Although the present study was focused on the extent of coverage of IAPS over the Beeshazari Taal and its effects on the wetland-dependent birds, this study was limited by the time constraint. This study was conducted only for six months and especially during the winter season up to spring; therefore some other species and summer visitors might not be included in the list. Another limitation was the fact that this study was conducted only within the Beeshazari Taal, so many bird species found in the other nearby wetlands were also unnoticed in this study.

2. OBJECTIVES

The main objective of the research was to analyze the effects of invasive alien plant species (IAPS) on the wetland-dependent birds. The specific objectives were:

1. to assess the extent and effects of coverage of invasive alien plant species over the lake;
2. to determine the composition of wetland-dependent birds species; and
3. to determine the diversity indices; and the similarity index along the different blocks of the lake.

3. STUDY AREA

This study was conducted in the Beeshazari Lake a Ramsar site, located at the Buffer Zone Area of Chitwan National Park of Central Terai, Nepal. Official size of the Chitwan National Park (CNP) is 932 km^2, but recent estimation from GIS analysis showed the total area to be 1,182 km^2 (DNPWC 2000). The CNP borders with the Parsa Wildlife Reserve in the east and the Valmiki Tiger Reserve of India in the south. The Narayani River marks the western boundary of the park, whereas the Rapti River marks the northern east boundary. CNP is also part of the Terai-Duar Savanna Grassland; one of the Global 200 Eco-regions designated by the WWF and was declared a World Heritage Site by UNESCO in 1984.

The park covers a pristine area with unique ecosystems. Vegetation of the park consists primarily of Sal (*Shorea robusta*) forest occupying approximately 70% of the total area. In the higher reaches of the Churia hills, the vegetation gives way to Mixed Pine and Hard wood forest while along the river banks Grassland occupy approximately 20% of the total surface area, whereas riverine forest occupy about 7% of the total surface area of the park (DNPWC 2000, KMTNC 1998).

More than 600 plant species, 50 mammals, 526 birds and 49 reptiles and amphibian species have been recorded in CNP and remains one of the last habitats for the critically endangered Greater One-horned Rhinoceros (*Rhinoceros unicornis*), Royal Bengal Tiger (*Panthera tigris*) and Asiatic Elephant (*Elephas maximus*) (DNPWC 2000).

In 1996, an area of 750 sq. km. surrounding the park was declared as Buffer Zone, which consists of forests and private lands. The park officials and the local people jointly initiate community development activities and manage natural resources in the Buffer Zone. Government has make provisions for 30 to 50 percent of the park revenue to be retained for community development

activities in Buffer Zone and the revenue is disbursed through a Buffer Zone Management Committee and Users Groups (DNPWC/MFSC 1999).

3.1 Location of the Specific Study Area

Beeshazari Taal, a Ramsar site is located in Buffer Zone area of Chitwan National Park (27^0 37' 14" N and 84^0 28' 22" E) at an altitude of 256 m from the sea level (Bhandari 1998) at the Tikauli Forest in Gitanagar Village Development Committee of Chitwan. This forested wetland is surrounded by Tikauli Community Forest of Ratnanagar Municipality at east, Dakshinkali Community Forest of Gitanagar VDC at west and south and Bandevi Barandabhar Community Forest of Bharatpur Municipality at north.

3.1.1 Physical Description

Beeshazari Taal is the second largest natural lake in Nepal (area 100 ha) after Ghodaghodi Lake (area 138 ha). Its depth in the center varies from 3 m in dry season to 5 m in rainy season and is subjected to the flow of water in canal (Bhandari 1996). The total forested wetland area of Beeshazari and associated lake as listed in Ramsar site is 3200 hectares (RIS 2003).

This forested wetland is a part of Barandabhar Corridor Forest (BCF) that serves as a corridor for animals moving seasonally between Chitwan National Park in the south and the forest of Mahabharat range in the north (Bhandari 1998).

Before the construction of the Khageri irrigation canal in 1967 the lake was in a much-degraded condition. This irrigation canal provided great contribution for the conservation of the Beeshazari Taal. Few patches of small stream shaped marshy land locally known as ghols are impounded due to the construction of levee of the irrigation canal. The canal of Khageri Irrigation diagonally crosses the forested wetland. The mud filled dam along the southern slope of this wetland supported for the formation of Beeshazari Lake from water logging.

Fig. 1. Map of the study area: Beeshazari Taal (Lake).

The lake has many ramifications. Most of the branches have already undergone succession and other are on the verge of succession. Numerous wetlands are lying on either side of the canal. Other small lakes, swamps and ghols along the canal are Satrahazari Lake, Kabra Lake, Choubishhazari Lake, Kamana Lake, Laxmi Lake, etc.

The main source of water for the lake is predominately annual rainfall and canal. But there is a considerable amount of silt deposition over a period of time, which may be due to open connection with the canal that carries silt during the monsoon (Bhandari 1998).

Beeshazari Lake has become integral part of Khageri Irrigation system. Before the formation of the lake, a few patches of small stream shaped marshy lands lay scattered. It was only after the construction of the dike for the Khageri Irrigation canal that a dissected fern-shaped lake was created in the middle of the Sal forest. These wetlands alternate with slightly elevated ground were forest predominate. All these wetland and forests constitute a self-sustained ecological unit.

3.1.2 Geology and Soil

Geology of the area composed of hard rock, principally granite or quartzite and limestone of late Tertiary Siwalik origin which is characterized by the presence of large boulders carried from the north as outwash deposits (Bhandari 1998). It is generally undulating with high ground water table that causes waterlogging condition during the monsoon. The soil consists of deep sand, loam and silt loam (Bhandari 1998). Soils are largely alluvium left by meandering river courses. The core of the Siwalik consists mainly of sandstone, conglomerates, quartizites, shales, and micaceous sandstones (Soil survey of Chitwan, 1968). Important soil types common in park and buffer zone are Brown Shallow, Brown Black and Red soil, Black Soil, Brown Soil,

Wet Well Drained Soil, Poorly Drained Brow Soil and Well Sorted Dry Shallow Soil (KMTNC, 1999).

3.1.3 Hydrological Values

Water is received from direct precipitation during the monsoon and through inflow of Khageri canal. The lake water is supplied to the canal and the stream during the dry season. The catchment's area helps to control flooding in the Khageri canal and recharges the ground water or the streams (RIS 2003).

The Beeshazari Taal itself is drained to the west through an outlet, which is fed to the Khageri irrigation canal passing across the Barandabhar forest in east-west direction. Khageri river discharge ranges from 1 to 396 cusecs during different seasons of the year. The average monthly flood discharge of the Khageri Khola at the headwork site of the irrigation canal is measured to be 10 cusecs in August and 2.5 cusecs lowest in the months of March and April (Bhandari 1998).

3.1.4 Climate

The lake area is categorized by humid subtropical monsoon climate with three distinct seasons; viz; winter, spring and monsoon. The climate data for this study was taken from 2001 to 2004 recorded at Rampur station of Chitwan.

Mean annual precipitation was estimated to be 2436.03 mm for the period of 2001-2004 of which 80.5 % falls between June and September (Figure 2). The monthly precipitation ranged from 2.7 mm in December to 736.9 mm in July. The monsoon rain begins slowly from the middle part of June and reaches peak during late July and early August and continuous until September. November is relatively dry but there are frequent shower during January, February and March.

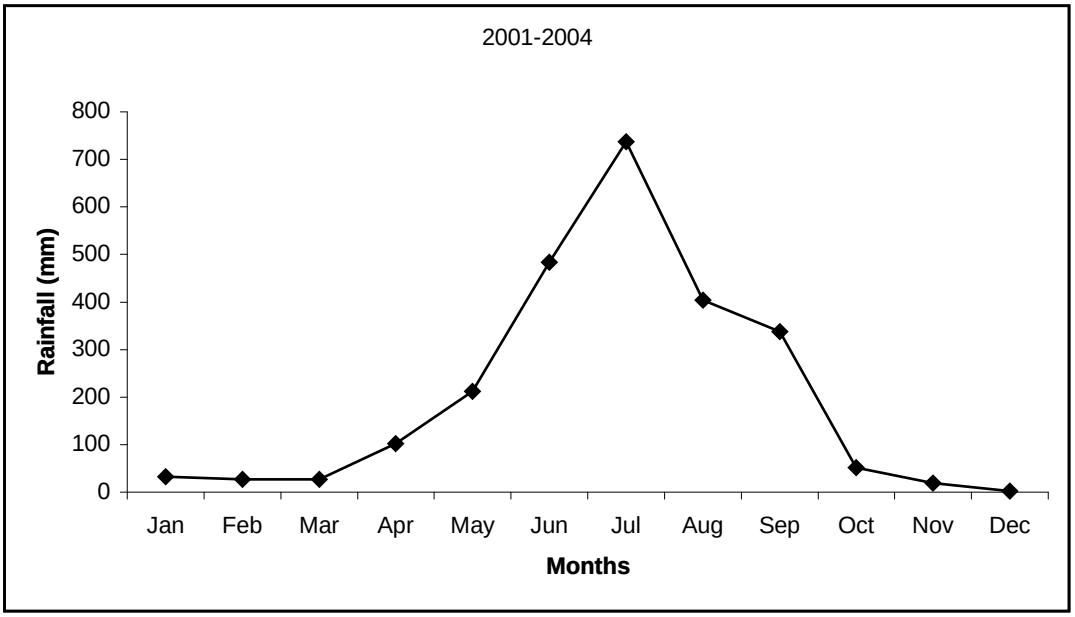

Figure 2: Mean monthly rainfall recorded at Rampur Station, Chitwan (2001-2004).

Mean monthly maximum and minimum temperature data shows that summer days are quite hot. The mean monthly temperature varies from 8.1^0 C during January to 34.8^0 C in April (Figure 3). Though mean maximum temperature was recorded in April warm weather continuous to May and June. Similarly January and February was also found relatively cold.

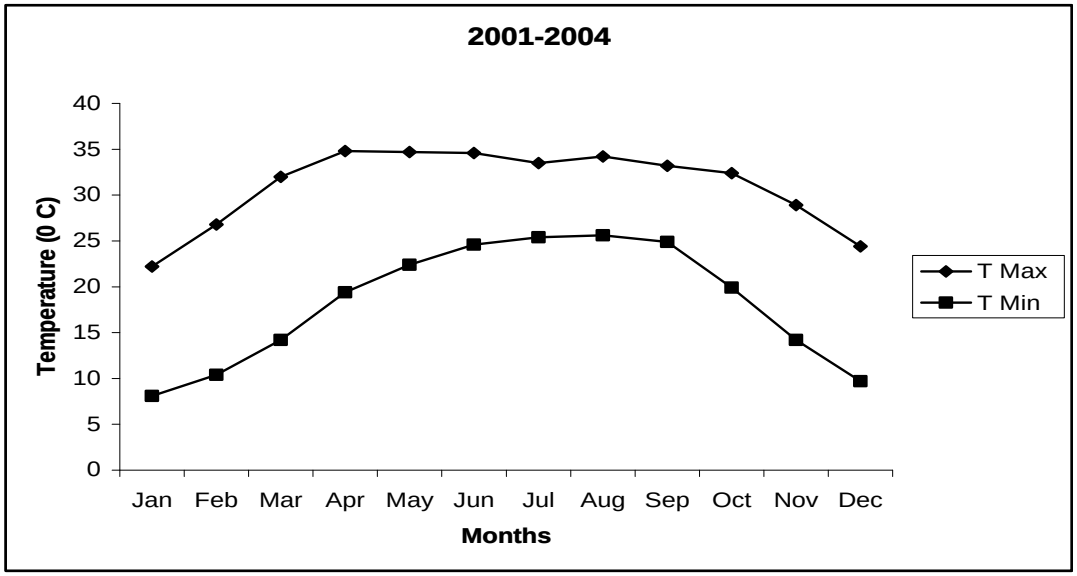

Figure 3: Mean monthly maximum and minimum temperature recorded at Rampur Station, Chitwan (2001-2004).

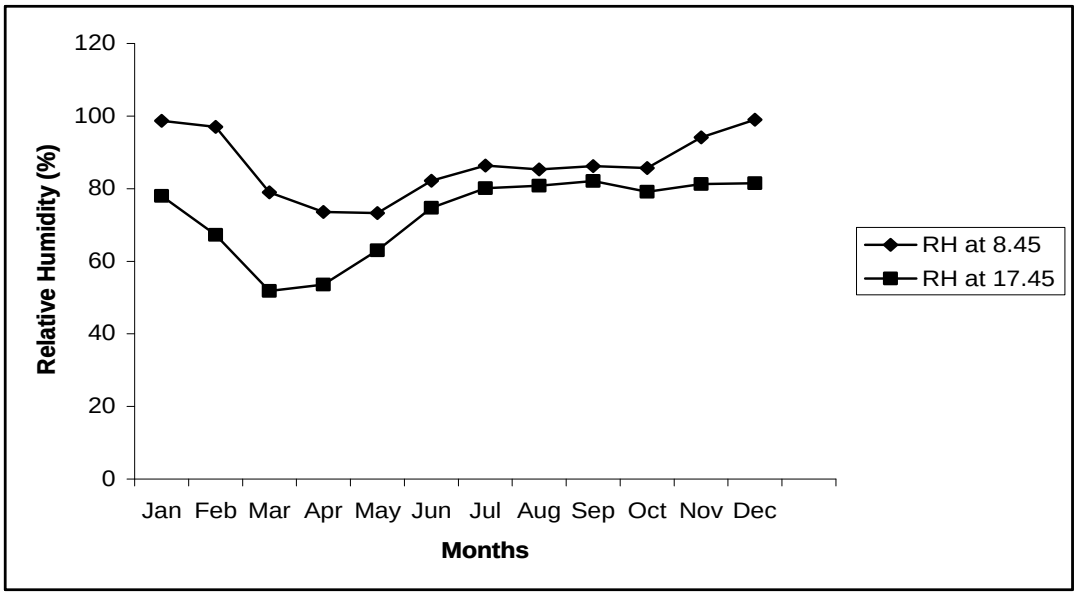

Figure 4: Mean monthly relative humidity at 0845 and 1745 hrs. recorded at Rampur Station, Chitwan (2001-2004).

Mean monthly relatively humidity varies from 51.8 % to 99 %. Highest values are recorded in December followed by January and February and least values were recorded in the months of May, April and March (Figure 4). In the same way at 17.45 pm maximum relative humidity was found in September followed by December and November and minimum relative humidity at that time was recorded in March followed by April and May.

3.1.5 Vegetation

Beeshazari Taal Basin is rich in biodiversity represented by 131 species of plants comprises 32 trees, 64 shrubs and 99 aquatic species (Bhandari 1998). The aquatic vegetation include 99 species consisting of 72 genera and 36 families of which 79 species are emergent in nature. The aquatic plants life forms inhabiting different zones of lake comprising 8 free floating plants, 7 submerged plants and 4 rooted floating broad-leaved plants.

The predominant tree species is Sal (*Shorea robusta*) mixed with the shrubs, herbs and grass. Other prominent associated species include *Terminalia alata,*

Bombax ceiba, Largerstroemia parvilora, and Acacia catechu, Michelia Champaca. (Bhandari 1998)

Eichhornia crassipes and Leersia hexandra are major aquatic plants that covers significant portion of the lake area. Other species that dominate the area comprises *Trapa bispinosa, Ipomoea aquatica*, *Potamogeton nodusus*, *Hydrilla verticillata* and *Nymphae nauchaelli*. In the periphery of the lake *Polygonum lapathifolium, Echinochola colona, Echinocola crus-galli, Panicum repens, Ipomoea fistulosa* are found more abundant. In the canal area the dominant species are *Potamogeton nodosu, Nymphoides cristata, Ipomoea aquatica* and *Trapa bispinosa* (Bhandari 1998).

Reed swamp formations are found in backwater in fingerlike projection, a characteristic of an ox-bow lake system. An extensive marsh meadow condition is found in the west just outside Khageri Irrigation canal corner. This indicates the autotrophic status of aquatic macrophyte cover and high sedimentation rate (RIS 2003). Other important flora species found in the lake are *Aerides odorata, Alstonia scholaxis, Certatophyllum demersum* etc.

The terrestrial land, which is also comparatively moist, provides a habitat for many sedges and moisture loving plants. In this habitat *Linderina pusilla* is dominant. This habitat also provides nutrient rich fodder and forage plants for domestic animals (Bhandari 1998).

3.1.6 Fauna

Seventeen species of fish have been recorded, of which *Channa striatus* is a hill fish found in the lake because the water of Khageri Irrigation feeds the lake. Other important fishes are *Ompok bimaculatus*, *Wallago attu, Heteropneustes fossils, Clarias batracus, Xenentodon cancila* etc (BPP 1995). Similarly, it harbours more than 45 species of herpetofauna (Yonzon, Habitat Himalaya 2000, Vol.III). The wetlands of the Beeshazari Taal system support 13 species of reptiles including 8 species of snakes, 1 species of Crocodile

(Marsh Mugger *Crocodylus palustris*), and 2 species of monitor lizards (Bengal Monitor Varanus bengalensis and Yellow Monitor *Varanus flavecens*) and 1 species of Indian soft-shell turtle (Yonzon 2000). The lake area also provides a suitable habitat for globally vulnerable Asiatic Rock Python *Python molurus*.

There have been very few systematic studies of the amphibians of the Beeshazari Taal area. Two species of amphibians *Rana cyanophlystis* and *Rana limmocharis* have been recorded from the area (RIS 2003).

A total of 273 species of birds representing 61 families have been recorded. Of the 273 species 60 species are wetland dependent (Baral et al 1998). A total of 84 species (30 %) are known in the lake area are Lesser Adjutant stork, Greater Spotted Eagle, Black-bellied Tern, Ferruginous duck and Pallas fishing eagle are globally threatened. The forested wetland habitat provides a refuge for a significant number of strokes, ibises, fishing eagles and lesser whistling teals. The meadow provides a good opportunity for egrets, herons and serpent eagle to forage upon snakes (RIS 2003).

Barandabhar Corridor Forest is an important corridor and refuge for the movement of large mammals from CNP between the Churia hills and Mahabharat range. In Beeshazari Lake Forest, a part of Barandabhar Corridor forest, Royal Bengal Tiger, Common Leopard and Spotted Leopard are recorded. The area also supports small population of Greater One-horned Rhinoceros, Spotted Deer, Barking Deer, Sloth Bear, Smooth-coated Otter and Fishing Cats.

3.1.7 Socio Economic Aspects

Three Village Development Committees (VDC) and two municipalities circumscribe the forest area, which houses Beeshazari Taal. Their total population is 162,887 with 34,652 households (DPC 2059). The major ethnic group comprises of Brahmin, Chhetri, Newar, Damai, Kami, Tamang, Magar and the indigenous groups like Tharu, Darai and Praja. Except indigenous

group, ethnic groups belong to the hill migrant community. The major crops grown in this area include paddy, wheat, mustard and maize. The other crops grown are buckwheat, millet, gram, lentil, etc.

Table 1: Population of adjoining VDC and Municipalities of the Lake.

Place	Household	Total Population	Male	Female	Literacy (%)	
					>6 years	>15 years
Gitanagar	2558	12281	6062	6219	80.55	63.8
Bachhyauli	1882	10508	5333	5175	70.1	50.1
Pathiyani	2287	10929	5292	5637	77.9	59.8
Bharatpur Municipality	20391	90473	46059	44414	80.0	62.2
Ratnanagar Municipality	7534	38696	19493	19203	81.95	60.9
Total	**34652**	**162887**	**82239**	**90648**		

(Source: District Profile of Chitwan; 2059)

The lake was used for fishing water storage for irrigation, grazing of cattle, fodder collection fuel wood and different aquatic plants. Fishing has been banned in this area. However collection of fodder and fuel wood from the lake area have been regulated and monitored by Buffer Zone Community Forest User Groups. The lake and its surrounding forest are noted for their scenic beauty. A number of tourist operators based in Sauraha offer regular visit to Beeshazari Taal area for their tourists especially for bird watching.

4. METHODOLOGY

4.1 Preliminary Survey

In order to find the most appropriate time of the day to survey water birds, a preliminary field survey was conducted from 11th to 13th of November 2004 at different times (hours) of the day in all study blocks from early morning (0600 hrs) to the late evening (1800 hrs). The main purpose of the preliminary survey was to determine the suitable time for the study of birds as well as to divide the lake area into blocks to cover a block each day as the lake area was big enough to cover it on a single day. After the completion of the preliminary survey, I had divided the whole lake area into five blocks, viz, Block 1, Block 2, Block 3, Block 4 and Block 5.

Fig 5. Map showing study blocks of Beeshazari Taal.

4.2 Weed Survey

The fieldwork was carried out from December 2004 to May 2005. The amount of coverage of invasive alien plant species was estimated from all study blocks once during preliminary survey. The approximation of coverage was based on visual observation through a grid system that was later on plotted with the help of GIS maps for the estimation of coverage area.

4.3 Bird Survey

Birds were counted with a direct counting method that was generally used if the congregation was no more than 3000 birds (Bibby *et. al.* 2000). This method was considered most appropriate since the study blocks were small and also there were small number of birds. Bird could be easily spotted so that it was assumed all birds within wetlands were counted (Dahal 2006). Weller (1999) described that birds in wetlands are best inventoried by direct count method where visibility is unobstructed, such as open water areas, mudflats and short-grass flats. In this study, bird species were identified and counted until all individuals within the field of view from the vantage had been tallied. Special attention was paid for the scarce and dispersed species especially for herons, egrets, and storks to ensure that effort is properly distributed.

Each block was surveyed in the morning on foot at a constant pace to ensure that each block was observed from suitable observation points from where all the individual birds were counted directly using binoculars (8 x 40 magnifications). I spent 20 minutes to each of the survey points and dividing the area using natural features to avoid double counting facilitated counting. The diameter of the point was 25 meters. Each block was surveyed once in each month thereby giving results for six surveys at the end of the study. It was assumed that I counted all bird species present in wetland blocks by visiting six times each block in order to reduce biases not including the secretive species (Vinicomble 1982). All blocks were counted on a cyclic basis with the same

pattern of visits being undertaken on each count. Bird species were identified in the field using standard field books to the birds of Nepal (Ali 1978; Grimmett et. al.1999; Inskipp & Inskipp 1991 and Shrestha 2001).

4.4 Data analysis

Different hours of the day were also categorized as early morning (0006-0008 hrs); late morning (0008-1100 hrs), afternoon (1100-1500 hrs) and early evening (1500-1800hrs). Best timing for the study of wetland-dependent birds was accessed during the preliminary survey. Migratory pattern and breeding status was also determined during the study. The birds in five blocks were characterized by using diversity indices to provide important information about rarity and commonness of species in a community. There are many diversity indices being used by ecologists to describe community composition and most of the indices that have been proposed have severe analytical or statistical drawbacks, and the application of different diversity measures to the same set of data may produce quite different patterns (Pielou 1975, Hurlbert 1971, Hill 1973). However I used two most widely used methods in the ecological literature: Shannon-Wiener Diversity Index (1949) and Simpson's Index (Appendix III).

4.4.1 Shannon-Wiener Diversity Index

Shannon-Wiener Diversity Index is one of the most widely used diversity indices in community ecology (Pielou 1975, Peet 1974) and provides a measure for the diversity of the total population of individuals in the species pool (Poole 1974). It assumes that all species area represented in a sample and that the sample is obtained randomly and it combines two measures, species richness (number of species) and evenness. However, it is hardly possible to include all species from the community in sample (e.g. rare species) that has been considered one of the major sources of error in this index (Sagar & Hasler 1969, Tramer 1969).

Evenness allows comparing the actual diversity value to the maximum possible diversity. Evenness (e) is constrained between 0 to 1, with 1 representing a situation in which all species are equally abundant (Magurran 1988).

4.4.2 Simpson's Index

Simpson's Index gives the probability of any two individuals drawn at random from an infinitely large community belonging to different species (Peet 1974). This index is considered a dominance index and is most sensitive to changes in the most common species (Peet 1974) and regarded as a measure of "dominance concentration" (Whittaker 1965). If the probability is high that both individuals belong to the same species, then diversity of community sample low. Simpson's Index of Diversity (1-D) is calculated by subtracting D by 1 to overcome the dominance error. The value of this index also ranges between 0 and 1 and greater the value, the greater the sample diversity. The reciprocal of Simpson's Index (1 / D) is calculated dividing by 1 and it is suggested for general application (Peet 1974).

4.4.3 Sorensen's Similarity index

Sorensen (1948) developed an index called the Sorensen's Similarity Index (Appendix III), which is used to compare the species diversities of two systems. This index shows the extent of similarity of sample plots and sides in term of total and common species present in two different study blocks (Sorensen 1948).

5. RESULTS

5.1. Bird presence over the day

The preliminary study reveled that early morning (0006-0008 Hrs.) was the best time to survey wetland birds at Beeshazari Taal. Comparing the result throughout the day, the number of bird species and total individuals were found to be relatively high in the early morning, compared to the rest of the day.

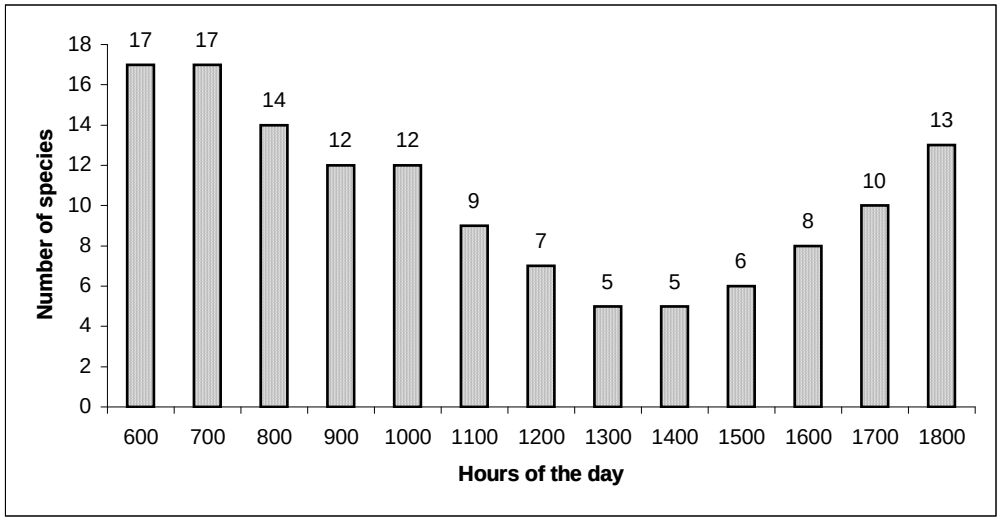

Fig 6. The number of bird species recorded at different times (hours) of the day.

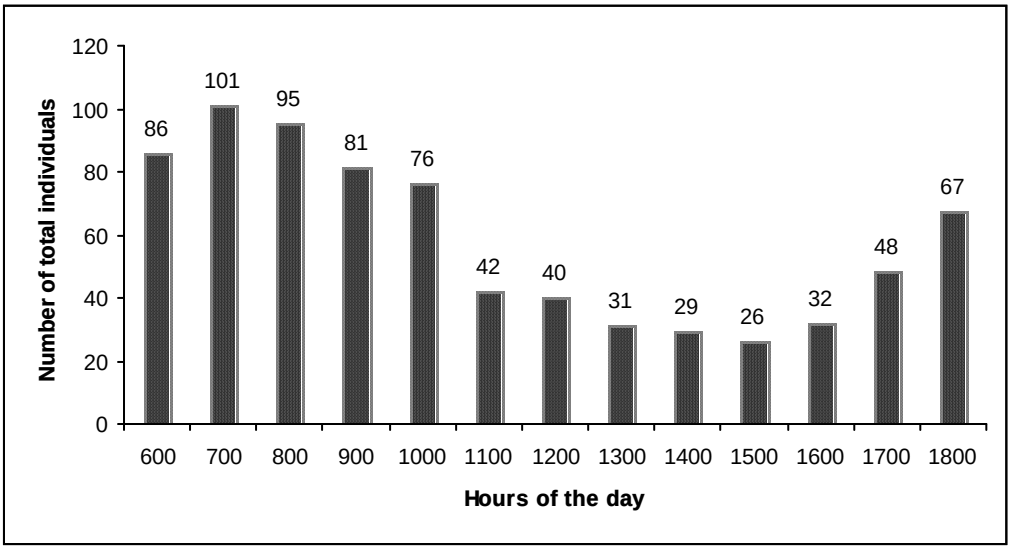

Fig 7. The total individuals of bird species recorded at different times (hours) of the day.

The highest numbers of bird species and total individuals were recorded in the early morning compared in the late morning and in the afternoon number decreased. A small increase in both bird species and total individuals was found in the early evening (Fig 6 and 7).

5.2 Weed coverage

Although there were many aquatic floating and submerged plants, two species of main invasive alien plant species; Water hyacinth (*Eichhornia crassipes*) and American cutgrass (*Leersia hexandra*) were recorded from the study zones. There was variation in coverage of weeds in different study blocks (Table 2). American Cutgrass (*Leersia hexandra*) was one of the most dominated and abundant among available species.

Fig 8. Map showing the coverage of IAPS over Beeshazari Taal.

Table 2: The coverage of two invasive alien plant species at the different blocks.

Block No.	Weed coverage	Major invasive alien plant species
1	65%	Water hyacinth and American cutgrass
2	80%	Water hyacinth and American cutgrass
3	55%	Water hyacinth and American cutgrass
4	75%	American cutgrass
5	65%	American cutgrass

5.3 Bird Diversity Indices

5.3.1 Species Richness

A total of 18 species of birds belonging to 04 orders and 11 families were recorded from all five blocks of the study area (Appendix I). Comparing the number of species recorded over five blocks of Beeshazari Taal; the highest number of bird species was recorded from block 3. The second highest number

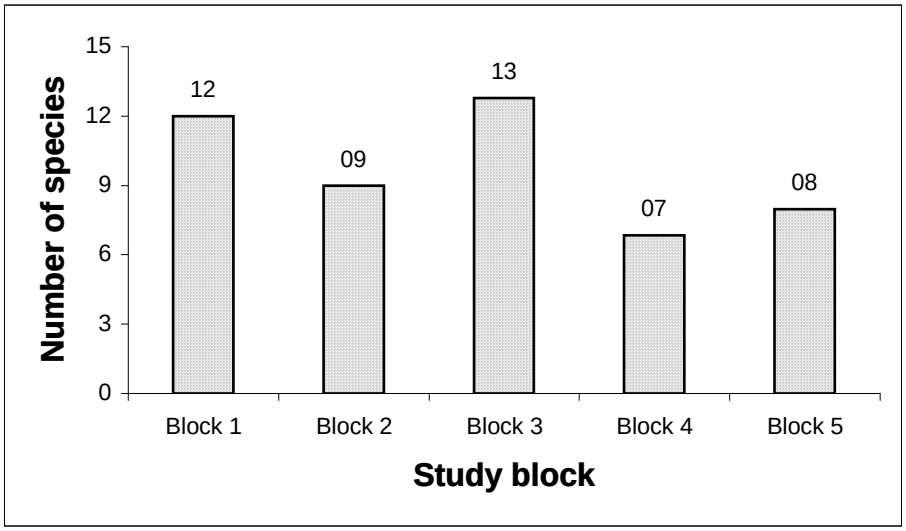

Fig 9. The number of bird species recorded at different study blocks.

of bird species was recorded from block 1 followed by block 2 and block 5 and then block 4 (Fig. 9).

Block 1 was dominated by Bronze-winged Jacana (*Metopidius indicus*) and Asian Openbill Stork (*Anastomas oscitans*). Four bird species; Cattle Egret (*Bubulcus ibis*), Intermediate Egret (*Egretta intermedia*), Grey heron (*Ardea cinerea*) and Crested Serpent eagle (*Spilornis cheela*) were found in block 1, but not in other blocks of the study area.

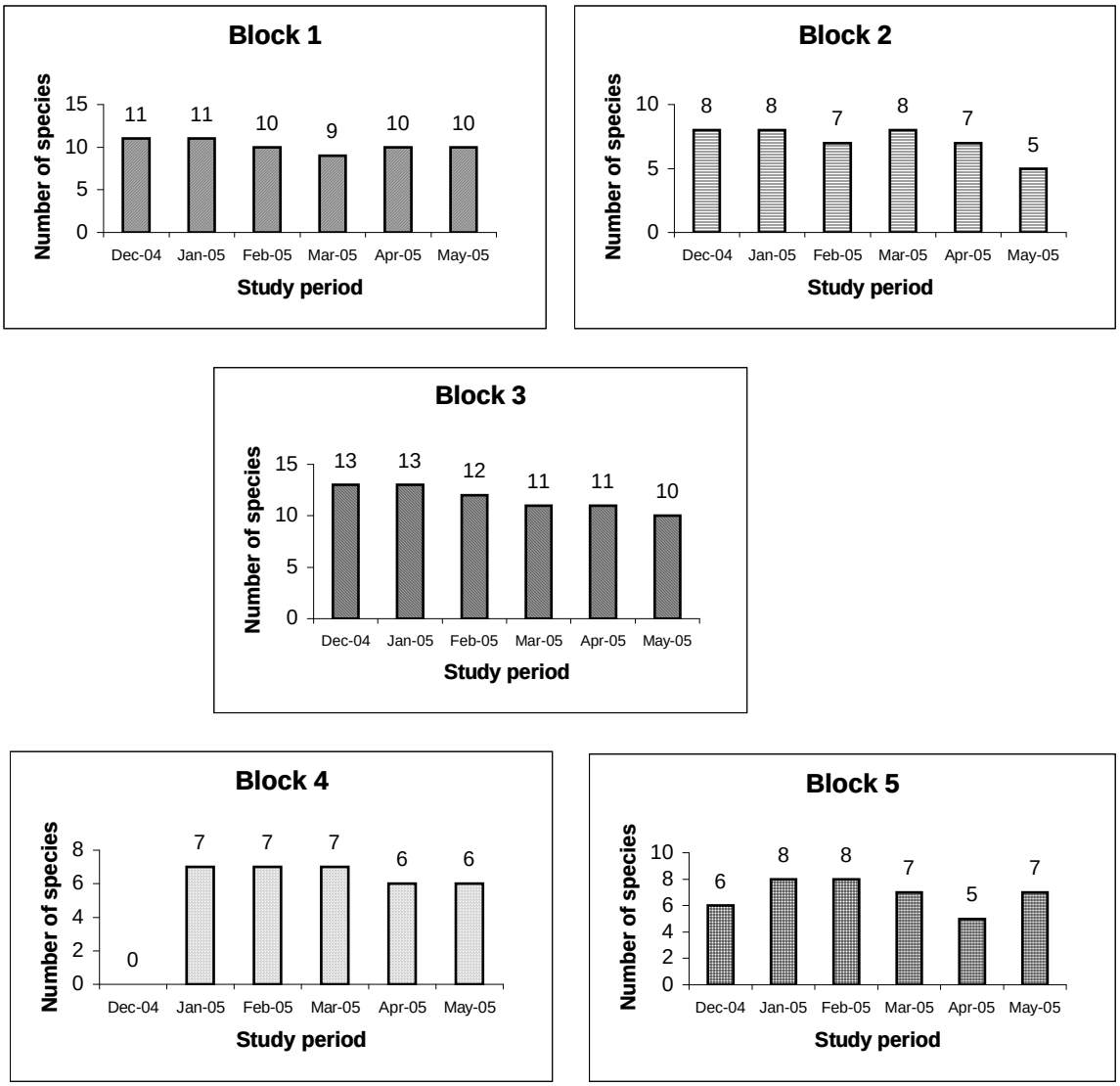

Fig 10. The total number of bird species recorded in all study blocks.

There were some records bird species in block 3 but not recorded in other blocks. These were; Great Cormorant (*Phalacrocorax carbo*) and Grey-headed fishing eagle (*Ichthyophaga ichthyaetus*). The minimum number of species was recorded from block 4.

The species numbers varied seasonally at the study area. The number of bird species slightly increased during December and January in block 1(Appendix III). Similarly in block 2, the number of bird species gradually increased during December and January and then declined from March (Appendix IV).

Likewise in block 3, the number of bird species gradually increased during December and January and then declined from March (Appendix V). The number of bird species slightly increased during January and February in zone (Fig 9).

Of the 18 bird species recorded, 5 species were migratory. The highest number of migratory bird species were recorded in block 3 and followed by block 2. The results showed that the new visitors gradually increased in December, reached a maximum in January and became stable until February. The numbers of migratory bird species at the study area were highest in block 3 and lowest in block 1 and 5 (Fig. 11).

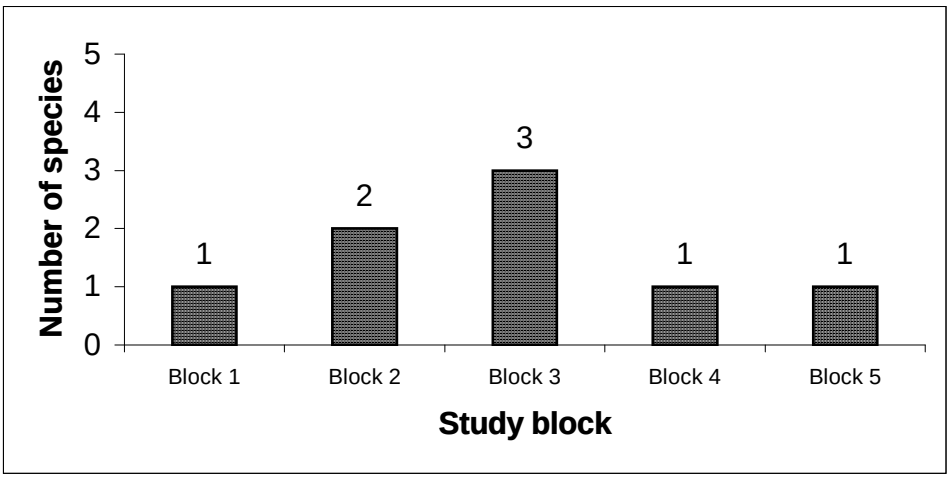

Fig 11. Number of migratory bird species recorded.

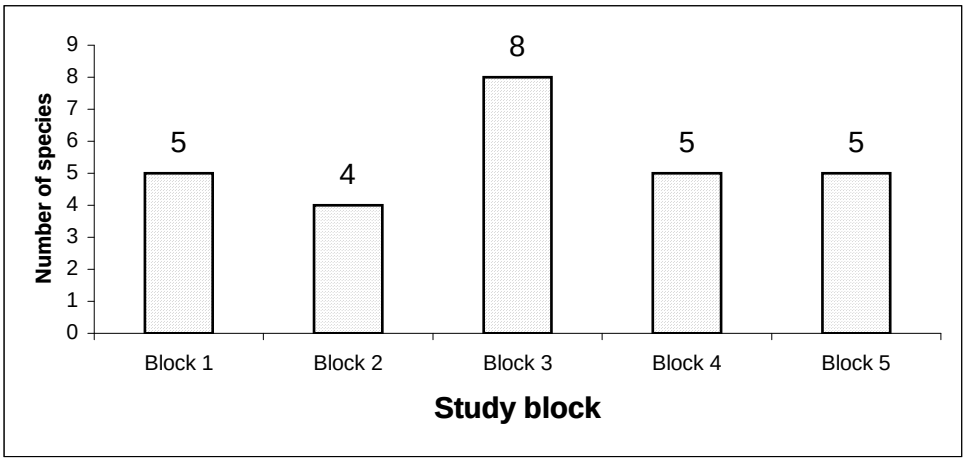

Fig 12. Number of breeding bird species recorded.

Of the 18 bird species recorded, 10 species were found breeding near lake area. The highest number of breeding bird species were recorded in block 3 and followed by blocks 2, 4 and 5. The numbers of breeding bird species at the study area were highest in block 3 and lowest in block 1 (Fig. 12).

Among the recorded species Bronze-winged Jacana (*Metopidus indicus*), Asian Openbill Stork (*Anastomas oscitans*) and Great Cormorant (*Phalacrocorax carbo*) were encountered most frequently at each of the surveys. Bird species such as Woolly-necked Stork (*Ciconia episcopus*), Grey-headed Fishing Eagle (*Ichthyophaga ichthyaetus*), Crested Serpent Eagle (*Spilornis cheela*) and Common Sandpiper (*Actitis hypoleucos*) were observed the least from the study area. Intermediate Egret (*Egretta intermedia*) and Grey Heron (*Ardea cinerea*) were recorded once from block 1 only.

5.3.2 Bird abundance

The total number of bird individuals counted from different study zones varied between December and May (Appendix II). The general trend of the bird population increased in December and decreased in February (Fig 9). Block 3 supported largest numbers of individuals followed by block 4, block 1 and

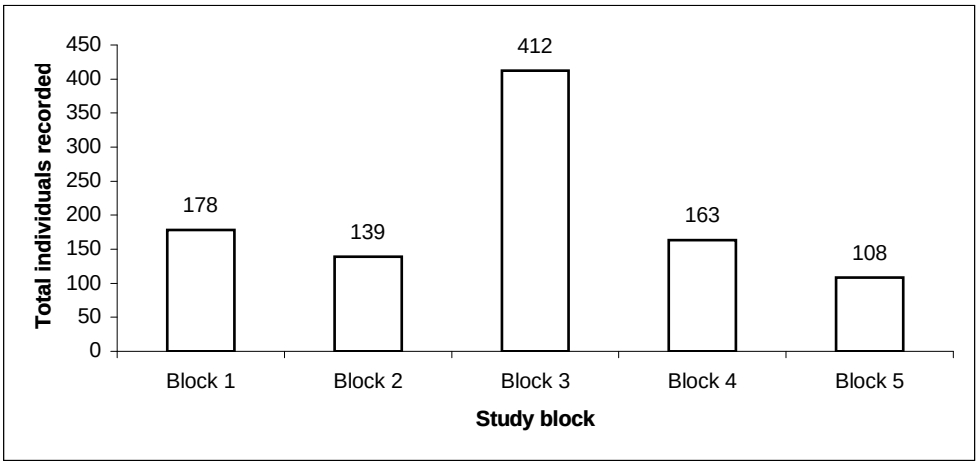

Fig 13. The total number of bird individuals counted in different blocks.

block 2 and then block 5. The results showed that largest numbers of bird individuals were recorded during the month of December and January (Fig 13).

Of 11 families, the Ardeidae with 4 species of birds followed by the Ciconiidae with 3 species of bird contributed strong hold in bird population. Halcyonidae and Accipitridae followed it with 2 species each. A small number of individuals came from the rest of the families such as Jacanidae, Phalacrocoracidae, Alcedinidae, Threskiornithidae, Anhingidae, Rallidae and Scolopacidae (Fig 14).

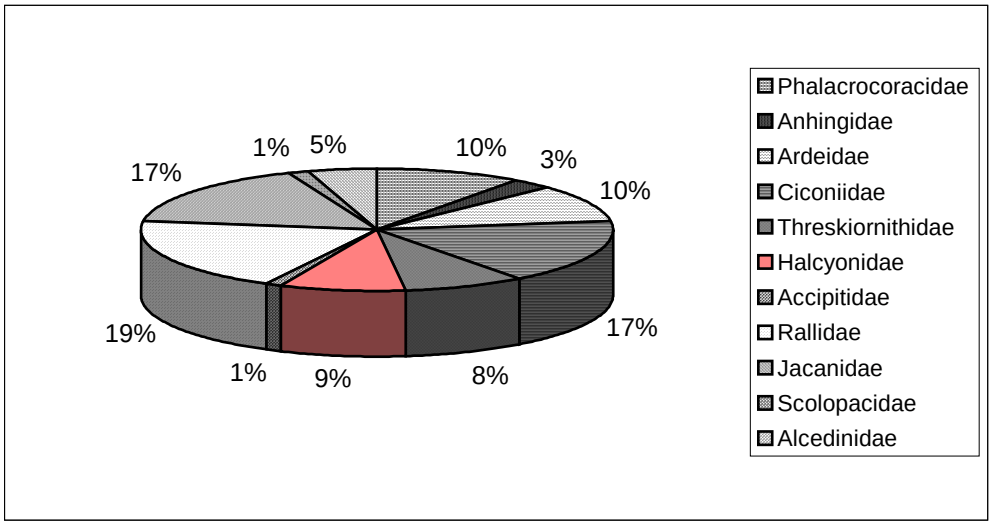

Fig 14. The total number of individuals (%) belonging to different families.

5.3.3 Shannon-Wiener Diversity Index

The Shannon-Wiener Index varied between blocks of the study area. Block 1 supported highest bird diversity. The second highest bird diversity was obtained in block 3 and subsequently in the block 5 and block 2. The study found that the bird diversity was least in block 4 of the study area (Table 3).

Table 3. Shannon-Wiener Diversity Index, Maximum possible value of Shannon-Wiener Index and Evenness Index of data samples.

Blocks	Shannon-Wiener Diversity Index (H)	Maximum possible value of Shannon-Wiener Index (H_{max})	Evenness Index (e)
Block 1	2.256	2.485	0.908
Block 2	1.779	2.197	0.810
Block 3	2.236	2.565	0.872
Block 4	1.881	1.946	0.931
Block 5	1.923	2.079	0.925

The maximum possible value of Shannon-Wiener Index was found highest in block 3 compared to the rest of the blocks (Table 3). It was followed by block 1, block 2, block 5 and block 4 respectively.

The evenness of species in the community varied with response to survey blocks. Highest in block 4 followed by block 5, block 1, block 3 and block 2 respectively (Table 3).

5.3.4 Simpson's Index of Diversity

The Simpson's Index of Diversity varied between blocks of the study area. Block 1 supported highest bird diversity. The second highest bird diversity was obtained in block 3 and subsequently in the block 5 and block 4. The study found that the bird diversity was least in block 2 of the study area (Table 4).

Table 4. Simpson's Index and Simpson's Index of Diversity of data samples.

Blocks	Simpson's Index D	Simpson's Index of Diversity (1-D)
Block 1	0.124	0.876
Block 2	0.222	0.778
Block 3	0.132	0.868
Block 4	0.183	0.817
Block 5	0.163	0.837

5.3.5 Species Similarity

Among 18 species recorded, three species were recorded from all five blocks. Six species of birds were found in only one block throughout the study period.

Table 5. Sorensen's Similarity Index of data samples in the study area.

Sorensen's Similarity Index				
Blocks	**Block 2**	**Block 3**	**Block 4**	**Block 5**
Block 1	57.14	56	63.16	70
Block 2		81.82	50	70.59
Block 3			60	66.67
Block 4				66.67

Highest degree of similarity exists between block 2 and block 3. Similarity between block 2 and block 5 was following it and then between block 1 and block 5. Similarly, the similarity index between block 2 and block 4 was lowest (Table 5).

Along with the invasion of Invasive Alien Plant Species another threat to the Beeshazari Taal is its easy access by humans. A graveled road connecting Tikauli and Gitanagar VDC is running parallel to the lake along with the Khageri Canal. The local people use this road extensively throughout the day. Similarly, another way from Bharatpur Municipality through Baruwa Gate is also used by people to collect fodder and for picnic purposes. It is surrounded by the dense habitations of 3 Village Development Committees and 2 Municipalities (Aryal 2006).

6. DISCUSSION

The number of bird species and population abundance were found vary at different times of the day from early morning to late evening. I conducted surveys in the morning because the highest number of bird species and individuals were recorded compared to the rest of the day in the study area. Avifauna are very active during the morning and evening with little activity during the rest of the day thereby giving highest opportunity for maximum observation of the bird species and total individuals within the study area. These findings are largely consistent with many bird researches. The activity and song output are greatest near dawn, low during the middle of the day, and increase again close to dusk (Robbins 1981, Lay 1938) and thereby giving the best result in the early morning compared to later (Grinnell and Storer 1924, Lay 1938). However wetland birds are not easily monitored by the standard census techniques (Bibby *et. al.* 1992) because of the diversity in their behaviour. Therefore, I consider these as the underlined biases and assumed that some of the highly shy, secretive and nocturnal species might not have included into this study because the survey was conducted only during the day time and because only a direct count method was used. Accurate censuring of wetland birds requires a variety of techniques, including nocturnal surveys, nest counts, intensive efforts involving walking or canoeing through marshes, and the use of recorded calls to elicit responses (Weller 1986). The poorest sighting of the birds were made during the middle of the day was probably due to the effects of the time of day, when birds are generally inactive.

During the study period of six months, only 18 species of wetland-dependent birds were recorded, which is an alarming situation for these birds' future status. The coverage of IAPS up to 70% indicates that the habitat is degrading day by day for the wetland-dependent birds. These results indicate that bird species composition depends on the degree of invasion by invasive alien plant species and availability of open water body. The similarity in species

composition decreased significantly with the increasing coverage of IAPS. The widespread distribution of IAPS has a significant role to decline the number of bird species and total individuals through reduction of the potential foraging ground for water birds.

Several researches reported that there was a sharp decline of water birds from Beeshazari Taal (Baral 1999, Baral and Inskipp 2004). Some important species of waterfowl such as Lesser Whistling Duck and Common Coot that were in the past regularly sighted species in the area (Baral 1999). However during this study, there were no records of these species. This comparison is presented here because during the period of late 1990s, Beeshazari Taal have had less abundant of the water hyacinth (Bhandari 1996) and supported a large number of wetland birds (Baral 1999). The declining of birds started when invasion rapidly expanded to wetland areas of Beeshazari Taal.

There was a decrease in the abundance of the wetland bird species with the increasing invasion of the IAPS. The results showed that block 3 has supported the highest number of bird species and population compared to the rest of the blocks that could probably because of lowest invasion. Therefore, the highest population abundance of bird species in block 3 was probably due to following reasons:

1) the block 3 was itself bigger in size than the rest with maximum open areas,
2) the surrounding vegetation was woody mainly composed with *Shoera robusta* and *Bombax cebia* and these are the best roosting plant species for large wading birds particularly for egrets, cormorants, herons, ibises and storks, and therefore block 3 supported large number of wader bird species and,
3) there was poor visibility and surrounding areas was densely vegetated so that people access was limited to this wetland block. Additionally, there were less human disturbances compared to the other blocks.

Block 2 was small in size and had a significant amount of coverage (80%) of IAPS in comparison to block 3 (55%) and reduced the numbers of bird species and population abundance. The results suggested that if the area is significantly invaded by IAPS, the size of the wetland habitat itself does not support some bird species. It indicates that the amount of invasion played a significant role in making differences in community composition. The results also suggested that the open water area is most important for wetland dependent birds even if the area is less disturbed. Block 4 was almost covered (75%) by IAPS and therefore supported very few bird species.

Bird distributions within water-bodies are often related to prey densities. The substantial coverage of IAPS greatly reduces the invertebrate community due to the reduction of dissolved oxygen concentration (Masfiwa et. al. 2001). The oxygen concentration regulates the invertebrate distribution and has an effect on the waterfowl population and distribution since these birds largely feed on a wide range of the invertebrate community and small fishes. Madsen (1997) found that water covered by water hyacinth had the lowest dissolved oxygen level as compared to water covered by milfoil, hydrilla, pondweed and a native mix of submerged plant and was the only plants to have averages below 5 mg/L concentration of oxygen. This oxygen concentration level below the 5 mg/L is notable because it represents the level at which many fishes start to experience oxygen stress (Madsen 1997). These results suggest that oxygen concentration is most important for the population dynamics of invertebrate communities and might altered the food web of wetland bird communities. Additionally, the biggest ecological threat posed by IAPS is the disruption of the entire ecosystem, often by invasive plants that replace native and provide poor habitat for native animals (Richard et. al. 2000). Thus water hyacinth infestations shade out submerged plants, crowd out emerged plants and reduce biological diversity (Grodowitz 1998).

Besides these factors, availability of food determines the population abundance of bird species. It was found that food limitation might influence individuals' reproductive success and survival and limit the number of breeding individuals and population densities (Boutin 1990). My results showed that there were sharp declines or even disappearance of some of the important dabbling species particularly; Lesser whistling duck, Common Coot and Cotton-pygmy goose which indicates poor habitat quality when considering them as an indicator for the evaluation of wetland condition (Urfi *et. al.* 2005). However the occurrence of IAPS as a narrow fringe of vegetation (in contrast to a blanket over the water surface) provides a rich habitat for diversity of macro invertebrate communities (Masfiwa et. al. 2001), thus supporting certain types of bird species.

It was found that it’s not totally true for water hyacinth that it causes only the negative effects on the ecosystem. Even it seems useful in some instances. Some species of bird prefer the water hyacinth since its roots provide a favorable habitat for bird’s prey in which invertebrate densities amongst roots can range from 3446 to 138000 individuals per square meters (O'Hara 1967).

The study found that some water bird species such as Common Moorhen, Bronze-winged Jacana, Indian Pond Heron and Cattle Egret were highly adaptable species and was found in all blocks regardless of the intensity of the invasion. The high population of Common Moorhen indicates a preferred habitat in the water hyacinth mats because the species was found nesting on water hyacinth mats and most often obtained prey that were located near the perimeter of the mats (Bartodziej & Weymouth 1995). Likewise the Bronze-winged Jacana prefers floating and emergent vegetation habitat and eats small aquatic invertebrates which were gleaned from vegetation at the water surface but they also take small seeds and other plant matters (Butchart 1998). These bird species usually feed on seeds by walking or standing in shallow water over the vegetation of wetlands and used them as hiding and foraging ground. These

findings suggested that the water hyacinth could serve as a potential habitat for some of the bird species.

Nevertheless, deliberate management of water hyacinth for birds' habitat is doubtful, due to their extremely high growth rates and potential impact to other ecosystem components (Gopal 1987). There are many ways to control the water hyacinth and American cutgrass mainly; manual removal, aquatic herbicides and biological control agents.

Grodowitz (1998) report excellent control of water hyacinth by the use of the aquatic herbicides like 2, 4-D, diquat and combination of diquat and complexed copper. Herbicides are chemicals used to control invasive plants and, depending on the target species, can be applied directly to a plant, in the soil at a plant’s base, or even to the soil before seeds develop (The Nature Conservancy 2005). Grodowitz (1998) found that the release of the insects have been proven very successful in United States for the biological control of water hyacinth. These include two weevil species *Neochetina eichhorniae* and *N. bruchi* (Coleoptera: Curculionidae), a moth *Niphograpta albiguttalis* (Lepidoptera: Pyralidae) and a water hyacinth mite *Orthogalumna terebrantis* (Acarina: Galumnidae).

Mechanical control, however, is extremely labour intensive and requires a large time investment, as treatments must often be applied several times to ensure success (The Nature Conservancy 2005). Commonly implemented control methods for plants include hand pulling, mowing, girdling (removal of tree bark), and burning (The Nature Conservancy 2005). Chemical control uses the application of chemical compounds to prevent invasive species spread. This method of control can be very effective in both large and small areas, but is often criticized due to the possible contamination of land and water resources and a lack of target specificity that can result in the killing of desirable plant and animal species (National Park Service 2004).

Because diversity indices have drawbacks and any one of the methodology for the diversity indices are not sufficient to characterize the community / species (Sagar & Haasler 1969), I used tools that have been used in community ecology such as Shannon-Wiener Diversity Index (H), Simpson's Index (D) and Simpson's index of Diversity (1-D) to characterize the community as well as species. The results thus obtained gave us an impression to find out the differences that how different methods measured species diversity even using the same data set. Additionally, it also allows us to see the effect of species number and abundance on bird diversity measures in different blocks of the study area.

The Shannon-Wiener Index varied between blocks of the study area. My study found that the diversity is high in the areas where there is a condition of open water along with some of the water surface covered by floating plants that facilitates the birds for foraging as well as for movement across it. Block 1 supported highest bird diversity (Shannon index, H = 2.236) because of the very reason that it is having open water surface with some part of it covered by the water hyacinth and American cutgrass. Similar type of results was obtained by Simpson's Index of diversity with a slight difference but not the very large. Highest degree of similarity exists between the blocks with the minimal coverage of IAPS. Blocks infested by IAPS were having the least similarity and even less abundance of bird species.

7. CONCLUSION

The results revealed that invasion of IAPS on wetland area caused the reduction of wetland dependent bird species and the total individuals due to substantially reduction of foraging and breeding grounds. The IAPS; water hyacinth and American cutgrass provide nesting grounds for a few species to some extent and may have some other positive effects but eventually they pose a great threat for freshwater ecosystems, particularly for wetland dependent birds. The blocks with a high degree of invasion had lower bird diversity in comparison to the blocks with minimum amount of invasion. However the results showed that certain species were found to be dominant in the community associated with water hyacinth. There were a significantly high number of individuals of some species e.g. Common moorhen and Bronze-winged jacana in the habitat associated with extensive coverage of IAPS.

As study found that invasive weed has posed the serious threat to wetland bird community, it is most important to look at the management of the invasion. There are many ways to control the water hyacinth and American cutgrass mainly; manual removal, aquatic herbicides and biological control agents.

There had been a few efforts of removing water hyacinth from the lake in past and had a positive impact on wetland dependent bird species and I recommend that the continuation of such programmes should be given. The IAPS should be removed periodically from the wetland sites before the arrival of wintering wetland dependent birds. The appropriate time for these works could be between August to Mid-October of the year.

If the management delays, water hyacinth likely would return to infestation levels that would requires huge amount of money and labour to return for maintenance levels.

Beeshazari Taal is one of the most disturbed lake in Nepal, owing to its easy access as along with Khageri Canal, a road connect Tikauli to Gitanagar is the main way for the movement of people. Similarly, another way from Bharatpur Municipality through Baruwa Gate is also used by people to collect fodder and for picnic purposes. It is surrounded by the dense habitations of 3 Village Development Committees and 2 Municipalities (Aryal 2006). The lake area is surrounded by a human population of more than 1, 60,000 mostly indigenous community and hill migrants (Aryal 2006) who have a relatively lower level of awareness. These factors in due course are potential barriers for natural resource management of Beeshazari Lake System.

With the aim of increasing local participation in conservation of natural resources, the Government of Nepal in 1995 declare this area along with some other adjacent areas of CNP as a Buffer Zone (DNPWC 2005). Bureau of Ramsar Convention on Wetlands of International Importance designated it as a Ramsar Site for its international ecological importance (2003). But still there are many things to do for the conservation wetland and their inhabitants.

8. RECOMMENDATION

1. **Periodic removal of Invasive Alien Plant Species:** Periodic removal of invasive alien plant species like Water Hyacinth and American cutgrass should be done. It helps in providing open water surface for the animals and submerged plants.

2. **Methods of controlling IAPS:** Inventory on the methods of controlling the prolific growth of IAPS should be conducted on National Level and should initiate some experimenting methods for its mechanical, chemical and biological control which could be beneficial on long term.

3. **Conservation of Wetland dependent birds:** Periodic removal of IAPS would allow the wetland dependent birds to enjoy their habitat in full extent, so it should be continued. Along with this, human disturbance should be minimized to a very low level along with strict regulations against killing of birds or any other animals or disturbing their habitats.

4. **Wetland Preservation:** Site of inlet and outlet for the lake should be reviewed once again technically and the dispute over the ownership also should be resolved quickly. A comprehensive long-term Management Plan for the Conservation of Beeshazari Taal is essential and should be formulated involving various stakeholders very quickly concentrating on the conservation of lake, its animals and plants, the local people and the sustainable development of the area.

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APPENDIX I

List of the wetland-dependent birds recorded during the study period from Beeshazari Taal.

Common Name	Zoological Name	Order	Family	Status (IUCN)
Great Cormorant	Phalacrocorax carbo	Ciconiiformes	Phalacrocoracidae	
Oriental Darter	*Anhinga melanogaster*	Ciconiiformes	Anhingidae	Near Threatened
Indian Pond Heron	*Ardeola grayii*	Ciconiiformes	Ardeidae	
Grey Heron	*Ardea cinera*	Ciconiiformes	Ardeidae	
Intermediate Egret	*Egretta intermedia*	Ciconiiformes	Ardeidae	
Cattle Egret	*Bubulus ibis*	Ciconiiformes	Ardeidae	
Asian Openbill Stork	*Anastomas oscitans*	Ciconiiformes	Ciconiidae	
Woolly-necked Stork	*Ciconia episcopus*	Ciconiiformes	Ciconiidae	
Lesser Adjutant Stork	*Leptoptilus javanicus*	Ciconiiformes	Ciconiidae	Vulnerable
Black Ibis	*Pseudibis papillosa*	Ciconiiformes	Threskiornithidae	
Common Moorhen	*Gallinula chloropus*	Gruiformes	Rallidae	
Bronze-winged Jacana	*Metopidius indicus*	Charadriiformes	Jacanidae	
Common Sandpiper	*Actitis hypoleucos*	Charadriiformes	Scolopacidae	
White-breasted Kingfisher	*Halcyon smyrnensis*	Coraciiformes	Halcyonidae	
Stork-billed Kingfisher	*Pelargopsis capensis*	Coraciiformes	Halcyonidae	
Common Kingfisher	*Alcedo atthis*	Coraciiformes	Alcedinidae	
Grey-headed Fishing Eagle	*Ichthyophaga ichthyaetus*	Ciconiiformes	Accipitridae	Near Threatened
Crested Serpent Eagle	*Spilornis cheela*	Ciconiiformes	Accipitridae	

APPENDIX II

Number of wetland-dependent birds recorded during whole study period (Block wise).

Common Name	Block 1	Block 2	Block 3	Block 4	Block 5	Total
Great Cormorant	0	0	99	0	0	99
Oriental Darter	0	8	16	0	4	28
Indian Pond Heron	14	14	14	15	16	73
Grey Heron	6	0	0	0	0	6
Intermediate Egret	4	0	0	0	0	4
Cattle Egret	19	0	0	0	0	19
Asian Openbill Stork	23	6	44	20	21	114
Woolly-necked Stork	0	6	8	0	0	14
Lesser Adjutant Stork	14	0	0	15	11	40
Black Ibis	0	0	36	47	0	83
Common Moorhen	42	46	57	37	27	193
Bronze-winged Jacana	23	42	66	36	0	167
Common Sandpiper	0	5	9	0	0	14
White-breasted Kingfisher	15	8	26	0	16	65
Stork-billed Kingfisher	6	4	9	0	4	23
Common Kingfisher	7	0	22	9	9	47
Grey-headed Fishing Eagle	0	0	6	0	0	6
Crested Serpent Eagle	5	0	0	0	0	5
Total	**178**	**139**	**412**	**179**	**108**	**1000**

APPENDIX III

Number of wetland-dependent birds recorded during different months in Block 1

Common Name	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Total
Great Cormorant	0	0	0	0	0	0	0
Oriental Darter	0	0	0	0	0	0	0
Indian Pond Heron	3	3	2	2	2	2	14
Grey Heron	2	1	1	1	1	0	6
Intermediate Egret	1	1	1	1	0	0	4
Cattle Egret	5	4	4	3	3	0	19
Asian Openbill Stork	7	7	5	2	2	0	23
Woolly-necked Stork	0	0	0	0	0	0	0
Lesser Adjutant Stork	5	3	3	2	1	0	14
Black Ibis	0	0	0	0	0	0	0
Common Moorhen	10	10	8	6	4	4	42
Bronze-winged Jacana	4	4	6	4	3	2	23
Common Sandpiper	0	0	0	0	0	0	0
White-breasted Kingfisher	3	2	3	2	2	3	15
Stork-billed Kingfisher	1	1	1	1	1	1	6
Common Kingfisher	1	2	1	1	1	1	7
Grey-headed Fishing Eagle	0	0	0	0	0	0	0
Crested Serpent Eagle	0	1	1	1	1	1	5
Total	**42**	**39**	**36**	**26**	**21**	**14**	**178**

APPENDIX IV

Number of wetland-dependent birds recorded during different months in Block 2

Common Name	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Total
Great Cormorant	0	0	0	0	0	0	0
Oriental Darter	2	2	1	1	1	1	8
Indian Pond Heron	2	2	3	3	2	2	14
Grey Heron	0	0	0	0	0	0	0
Intermediate Egret	0	0	0	0	0	0	0
Cattle Egret	0	0	0	0	0	0	0
Asian Openbill Stork	2	2	0	0	2	0	6
Woolly-necked Stork	3	3	0	0	0	0	6
Lesser Adjutant Stork	0	0	0	0	0	0	0
Black Ibis	0	0	0	0	0	0	0
Common Moorhen	5	6	8	8	10	9	46
Bronze-winged Jacana	4	6	6	8	9	9	42
Common Sandpiper	1	1	1	1	1	0	5
White-breasted Kingfisher	2	1	2	1	1	1	8
Stork-billed Kingfisher	1	1	0	1	0	1	4
Common Kingfisher	0	0	0	0	0	0	0
Grey-headed Fishing Eagle	0	0	0	0	0	0	0
Crested Serpent Eagle	0	0	0	0	0	0	0
Total	**22**	**24**	**21**	**23**	**26**	**23**	**139**

APPENDIX V

Number of wetland-dependent birds recorded during different months in Block 3

Common Name	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Total
Great Cormorant	27	27	21	12	12	0	99
Oriental Darter	3	3	3	3	2	2	16
Indian Pond Heron	2	3	2	2	3	2	14
Grey Heron	0	0	0	0	0	0	0
Intermediate Egret	0	0	0	0	0	0	0
Cattle Egret	0	0	0	0	0	0	0
Asian Openbill Stork	10	8	8	6	6	6	44
Woolly-necked Stork	2	2	1	1	1	1	8
Lesser Adjutant Stork	0	0	0	0	0	0	0
Black Ibis	11	9	9	7	0	0	36
Common Moorhen	11	9	8	9	10	10	57
Bronze-winged Jacana	10	10	12	12	12	10	66
Common Sandpiper	2	2	1	2	1	1	9
White-breasted Kingfisher	6	5	5	4	3	3	26
Stork-billed Kingfisher	2	2	2	1	1	1	9
Common Kingfisher	3	3	3	4	5	4	22
Grey-headed Fishing Eagle	1	1	1	1	1	1	6
Crested Serpent Eagle	0	0	0	0	0	0	0
Total	**90**	**84**	**76**	**64**	**57**	**41**	**412**

APPENDIX VI

Number of wetland-dependent birds recorded during different months in Block 4

Common Name	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Total
Great Cormorant	0	0	0	0	0	0	0
Oriental Darter	0	0	0	0	0	0	0
Indian Pond Heron	3	3	2	2	3	2	15
Grey Heron	0	0	0	0	0	0	0
Intermediate Egret	0	0	0	0	0	0	0
Cattle Egret	0	0	0	0	0	0	0
Asian Openbill Stork	4	4	4	3	3	2	20
Woolly-necked Stork	0	0	0	0	0	0	0
Lesser Adjutant Stork	2	2	3	3	2	3	15
Black Ibis	11	11	11	8	6	0	47
Common Moorhen	5	5	7	7	7	6	37
Bronze-winged Jacana	4	6	6	6	7	7	36
Common Sandpiper	0	0	0	0	0	0	0
White-breasted Kingfisher	0	0	0	0	0	0	0
Stork-billed Kingfisher	0	0	0	0	0	0	0
Common Kingfisher	1	1	1	2	2	2	9
Grey-headed Fishing Eagle	0	0	0	0	0	0	0
Crested Serpent Eagle	0	0	0	0	0	0	0
Total	**30**	**32**	**34**	**31**	**30**	**22**	**179**

APPENDIX VII

Number of wetland-dependent birds recorded during different months in Block 5

Common Name	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Total
Great Cormorant	0	0	0	0	0	0	0
Oriental Darter	1	1	1	1	0	0	4
Indian Pond Heron	2	2	3	3	3	3	16
Grey Heron	0	0	0	0	0	0	0
Intermediate Egret	0	0	0	0	0	0	0
Cattle Egret	0	0	0	0	0	0	0
Asian Openbill Stork	3	3	4	4	4	3	21
Woolly-necked Stork	0	0	0	0	0	0	0
Lesser Adjutant Stork	2	2	2	2	2	1	11
Black Ibis	0	0	0	0	0	0	0
Common Moorhen	4	4	4	5	5	5	27
Bronze-winged Jacana	0	0	0	0	0	0	0
Common Sandpiper	0	0	0	0	0	0	0
White-breasted Kingfisher	3	3	3	3	2	2	16
Stork-billed Kingfisher	1	1	0	0	1	1	4
Common Kingfisher	1	1	2	1	2	2	9
Grey-headed Fishing Eagle	0	0	0	0	0	0	0
Crested Serpent Eagle	0	0	0	0	0	0	0
Total	**17**	**17**	**19**	**19**	**19**	**17**	**108**

APPENDIX VIII

Shannon-Wiener Diversity Index

Shannon-Wiener Diversity Index was calculated as follows:

$$H = -\Sigma(n_i/N) \log (n_i/N)$$

where n_i/N is the proportion of individuals of a species (n_i) to the total number of individuals (N) in sample and S is the total number of species in the community (species richness).

The maximum diversity of a sample (H max) is found when all species are equally abundant. The maximum value of H for fixed species richness was calculated as:

$$H_{max} = ln\ (S),$$

where S is the total number of species.

Evenness (e) represents the relative distribution of individuals.

$$e = H / H_{max}$$

Simpson's Index of Diversity

Simpson's Index of Diversity was calculated as follows:

$$D = \Sigma(n_i / N)^2$$

The value of D ranges between 0 and 1 and with this index, 0 represents infinite diversity and 1, no diversity. Simpson's Index of Diversity (1-D) is calculated by subtracting D by 1 to overcome the dominance error.

Sorensen's Similarity Index

The index of similarity is expressed as

$$S = 2C / (A+B) \times 100$$

where A is the number of species in one site,
B is the number of species in another site,
C is the number of species common to both sites and
S is Sorensen 's similarity index.

APPENDIX IX

Water hyacinth (*E. crassipes*) over the lake area.

American Cutgrass (*L. hexandra*) growing over water hyacinth which provides bed for its germination.

American Cutgrass (L. hexandra) infestation over the Beeshazari Taal.

A herd of Black Ibis (*Pseudibis papillosa*).

Bronze-winged Jacana (*Metopidus indicus*) on an island of American Cutgrass (*L. hexandra*).

Lesser Adjutant Storks (*Leptoptilus javanicus*) foraging together.

A group of Great Cormorant (*Phalacrocorax carbo*) resting on a dry Sal (*Shorea robusta*) tree.

A group of Asian Openbill Stork (*Anastomas oscitans*) ready to fly.